87-04582/

This work was supported by the Federal Panel on Energy R/D (PERD).

Ce projet a reçu l'appui du Groupe fédéral de recherche et de développement énergétiques (GRDE).

Copyright 1986 by
National Research Council of Canada

Permission is granted to quote short excerpts and to reproduce figures and tables from this report, provided that the source of such material is fully acknowledged.

Copies of this and other publications of the Division of Energy may be obtained by mailing the appropriate remittance (a Bank, Express, or Post Office Money Order, or a cheque made payable to the Receiver General for Canada, credit NRC) to

Publication Sales and Distribution Office
National Research Council of Canada
Ottawa, Ontario
K1A 0R6

Price: Free

Copyright 1986 par
Conseil national de recherches du Canada

De courtes citations et la reproduction de figures et tableaux du présent rapport sont autorisées sous réserve que la source en soit clairement mentionée.

Des exemplaires du rapport et d'autres publications de la Division de l'énergie peuvent être obtenus par courrier sur le paiement d'avance des droits requis (règlement par mandat de banque, mandat-exprès, mandat-poste ou chèque payables au Receveur général du Canada, crédit du CNRC) à l'adresse suivante:

Bureau de vente et diffusion des publications
Conseil national de recherches du Canada
Ottawa (Ontario)
K1A 0R6

Prix unitaire: Gratuit

Disponible en français CNRC n° 26605

NRC PEAT PROGRAM OVERVIEW: 1982-1985

T.E. Tibbetts

April 1986

TABLE OF CONTENTS

	Page
INTRODUCTION	1
ORIGIN AND DEVELOPMENT OF PEATLANDS	2
CHARACTERISTICS OF PEAT	3
POTENTIAL USES OF PEATLANDS	5
PEAT AS AN ENERGY SOURCE IN CANADA: BRIEF HISTORY	6
THE PEAT PROGRAM	8
Origin	8
Structure/Mechanism	8
Objectives	8
Activities/Achievements	9
INTERNATIONAL PARTICIPATION	15
International Peat Society	15
International Energy Agency	15
PERSPECTIVES	17
National Policies for Peat Research and Development	17
Peatland Resource	18
Mining	18
Dewatering/Processing	18
Product Development - Carbon/Chemicals	19
BIBLIOGRAPHY	20
APPENDIX A	25
A1 POLICIES AND ACTIVITIES	25
A1.1 Peat Policies and Activities in Canada: Highlights	25
A2 RESOURCE AND INVENTORY	27
A2.1 Peat Resources of Canada	27
A2.2 The Use of Impulse Radar Techniques for Depth Profiling of Peat Deposits	27
A3 MINING	29
A3.1 Study of the Technology and Costs Associated with Dredging and Overburden clearing Operations for the Recovery of Peat	29
A3.2 An Evaluation of Alternative Wet Peat Mining Systems	31
A3.3 Development of Design Parameters for Peat Slurry Pumping and Pipeline Transport	34
A3.4 Design and Construction of Peat Slurry Pump/Macerator	37
A3.5 Peat Slurry Pumping Demonstration Project	40
A4 DEWATERING/PROCESSING	49
A4.1 Investigation of Transferable Technology for Application in Peat Dewatering Research	49

TABLE OF CONTENTS (Cont'd)

Page

A4.2 Process Evaluation and Conceptual Design of a Plant Based on a Technical and Economic Assessment of Peat Dewatering and Peat Fuel Processes 51
A4.3 Autohydrolysis and Fractionation of Peat via the UdeS-NRC Thermomechanical Process 55
A4.4 The use of Microbes in the Dewatering of Fuel Grade Peat - Part 1 57
A4.5 The Use of Microbes in the Dewatering of Fuel Grade Peat - Part 2 58
A4.6 Development of the Lamb Wet-Cell Burner for Energy from New Brunswick Peat 60
A5 ENVIRONMENT 62
A5.1 Identification of the Pollution Potential of the Harvesting and Preutilization of Peat as an Energy Commodity 62
A5.2 Wastewater Characteristics of Five Peat Dewatering Processes 62
A5.3 Pollution Potential of Peat Combustion, Liquefaction and Gasification 63
A5.4 Development of an Innovative Approach to Assess the Ecological Impact of Peatland Development: Ecological Background and Preliminary Model Development 64
A5.5 Fish and Wildlife Use of Peatlands in Canada 72
A6 PEATLAND DEVELOPMENT 74
A6.1 A Study on the Biogasification of Peat 74
A6.2 Anaerobic Fermentation of ORF Wetox^{R} Peat Pressate for the Production of Methane 76
A6.3 Carbon Products from Peat 78
A6.4 The Use of Peat Extracts/Pressate as a Feed Stock for Chemical and Biochemical Processes 84

LIST OF TABLES

1 Funding allotments 1

NRC PEAT PROGRAM OVERVIEW: 1982-1985

T.E. Tibbetts

INTRODUCTION

Peat displays some characteristics similar to coal and is sometimes referred to as "a young coal;" it also displays characteristics similar to wood and other forms of biomass and thus could be considered to be "old biomass." Both of these references are useful in rationalizing the research and development activities of a federal government peat research and development program, known as the Peat Program, carried out from 1982 to 1985.

The Peat (for Energy and Chemicals) Program was established under the auspices of the National Energy Program to promote research and development of Canada's immense peatland resources for energy and chemicals. It was terminated in 1985 following drastic budget reductions announced in November 1984. The growth in the activities of the Program is measured by the funding allotments shown in Table 1 for the three full years of the Program.

Table 1. Funding allotments

Activity	Peat Program resources: 1982-1985 ($ \times 10^3$)		
	1982/83	1983/84	1984/85
Inventory	225	360	340
Mining	50	240	320
Processing/dewatering	50	350	290
Environment	150	270	550
Product development/standardization	200	275	40

This report attempts to create among those unfamiliar with peat an awareness of the magnitude and importance of the peat resources and, particularly for the well initiated, to present a capsuled description of the Program and its accomplishments. The reader is urged to consult Appendix A containing executive summaries of the more mature projects and the Bibliography which documents the Program involvements.

ORIGIN AND DEVELOPMENT OF PEATLANDS

Climate played a leading role in the development of Canada's peatlands and for many their origin can be traced to the process of glaciation. Peatlands in Canada - bogs, fens, swamps, and marshes - represent about 12% of the total land area, i.e., about 111 000 × 10^3 ha, and were formed, as those elsewhere on the planet, some 10 000 years ago, coinciding with the wane of the last ice age.

For peatland presence and development, there must be a positive water balance. It requires the accumulation of organic material at a rate greater than its rate of decomposition. In the tropics the very high rate of decomposition in general prevents development of peatland. In desert areas the water balance is negative thus no peatlands develop. In a cool moist maritime climate a peatland cover can develop on almost any substrate and even on hill slopes; it is not restricted to depressions or lowland areas. As the ratio of precipitation plus water inflow to evaporation plus runoff decreases, and the ratio of organic debris accumulation to decomposition decreases, peatland development gradually becomes restricted and confined to lowland areas and local depressions.

Decomposition is mainly a disintegration of plant matter accomplished by micro-organisms. In a peat bog, the wet environment and accumulated plant debris limit air access to underlying layers of decaying vegetation. Not far below the wet surface oxygen is virtually absent, having been consumed by the disintegrating plant tissues and by the microbes that promote decomposition. Below that level decay can proceed only anaerobically, i.e., the micro-organisms that live in the lower levels depend on oxygen chemically stored in the plant residues. At greater depths, most of that source too has been consumed. Below the level of anaerobic activity virtually all change ceases. The process of disintegration stops before it has been completed, leaving the partially decomposed remains of the bog plants.

The large peat deposits in northern Europe, Asia, and North America are comprised of peat at the bottom, resting on the sand or clay or rock of what may once have been a lake formed by a receding glacier. At the top of the deposit one is likely to find living plants which if left undisturbed will die and make their own contribution to the process.

On the average it takes 3000 to 4000 years to accumulate a metre of peat; the accumulation continues only as long as bog plants can live, and die at the surface. Drainage and mining of peat terminate the process, a fact that contradicts impressions that peatlands represent a renewable resource. Unlike a forest which, with suitable care, can generate wood on a sustained yield basis, a peat deposit once mined is depleted. However, unlike a coal deposit, peatland may continue positive development if left undisturbed.

CHARACTERISTICS OF PEAT

Peat consists of the unconsolidated residues of aquatic plant life such as mosses, reeds, sedges, and to a lesser degree woody plants that have accumulated in a water-saturated environment over thousands of years. The properties of peat are determined largely by the original plant species and the degree of decomposition.

Peat contains a substantial portion of the carbon and hydrogen with which the original plant life was endowed. Entrapment of peat by movement of the earth's crust may lead to extremely high pressures and temperatures being brought to bear on the peat accumulation and beginning the process of "coalification" or "carbonization."

Peat is not included in coal classification and ranking systems; however, it is the first geological step in the formation of coal. The "coalification" process involves the loss of oxygen as carbon dioxide and water (incombustibles) and concentration of carbon and hydrogen (combustibles).

Peat is formed in a water-saturated environment and raw undrained peat contains about 90% water. The main components of peat that effect the combustion energy are fixed carbon and volatile matter which are of the order of 70 and 30%, respectively, on the dry ash free basis.

With age the increase in the fixed carbon is accompanied by a reduction in the volatile matter. Peat has about 60% more volatile matter by weight and has 25% less heating value than lignite coal. Peat is low in carbon and sulphur but has high oxygen and nitrogen contents compared to coal.

The elemental analysis of peat changes as decomposition proceeds. Decomposition results in plants losing their original character to become peat of variable composition ranging from material so slightly decomposed that the plants can be readily identified from leaves, stems, and roots to material so highly decomposed that it seems to be a thick structureless mud. The decomposition of lignin and similar substances of the original plant life yields humic acids - gelatinous colloids - which give peat its characteristic slippery feeling when handled.

It is essential to know the degree of decomposition of peat in order to gain a preliminary assessment of its use. A widely used system for determining the degree of decomposition, and essentially for field testing, is the von Post scale. The degree of decomposition, the H value, is expressed by a number on a 1 to 10 scale. H-1 represents totally undecomposed plant material and H-10 represents completely decomposed peat. In short, we can group peat as

(a) slightly decomposed, degree of decomposition H-1 to H-5, in which the residues of plants are recognizable; very small amounts of colloids or gels are present; the peat does not turn into hard lumps when it dries and it can be readily rewetted

(b) strongly decomposed, degree of decomposition H-6 to H-10, in which the residues of plants no longer reveal their generic origin; are highly colloidal (slippery); form very hard lumps when dried and the mass is difficult to rewet

Peat possesses properties that make it attractive to man, particularly those physical and chemical attributes which endow it with powers of aeration and water and nutrient retention when added to mineral soils. These attributes are particularly present in the relatively undecomposed peat material, H-1 to H-5, and have contributed to mankind's endeavours to satisfy at least two basic needs, food and recreation. In general, this peat is referred to as **peat moss**.

Energy uses demand relatively highly decomposed peat materials, H-6 to H-10, which is referred to as **fuel peat**. In general these peats have a higher inherent heat content. They have become consolidated to some degree - they are more dense - and therefore handling and transporting is technically and economically more attractive.

POTENTIAL USES OF PEATLANDS

There are many attributes of peatland that are becoming increasingly apparent and seemingly justify consideration of peatland as a valuable resource.

In Europe the use of peatland for forestry purposes has reached intensive levels. In Canada peatlands have been drained and converted for forestation, but mainly as research projects to date because of our still vast and readily available natural forest resources.

Some peatland has been drained and rendered productive for cattle grazing and for agriculture and market gardening projects. Blueberry and cranberry cultivation, Scotch pine and ornamental tree nurseries, and various market gardening projects have resulted from reclamation of peatlands. This activity is of growing significance in various parts of Canada, including Newfoundland, Quebec, Ontario, and British Columbia.

Some peatland has been drained and the peat removed, compressed, packed, and sold as peat moss for horticultural purposes. In Canada, peat is currently mined almost exclusively for horticultural purposes and there is a significant peat mining industry based on the horticultural value of the peat moss. These operations are carried out in Canada from coast to coast and are particularly significant in Québec, New Brunswick, Manitoba, and British Columbia. Current annual production of peat moss in Canada is about three quarters of a million tonnes with a value of more than $100 million. Most of the peat moss is exported to the United States with small quantities going to Europe, Japan, Africa, and South America.

Besides being used in situ for agriculture and forestry, and as a soil additive in horticulture, peat is mined and used in Europe as an energy feedstock. Most European countries with significant peat resources have re-evaluated their peatlands with a view to optimizing peat use and establishing priorities in the light of energy needs. Technology for utilizing peat for energy both on a large and small scale has been developed and in place for a number of years.

PEAT AS AN ENERGY SOURCE IN CANADA: BRIEF HISTORY

Peat is not commercially used for energy purposes in Canada or indeed in North America at a significant level.

Efforts to establish commerical use of peat fuel in Canada date back to the nineteenth century; for example, in 1864 a plant for the manufacture of peat fuel was established near Pulstrode, Quebec. In the early 1890's there was a marked revival of interest in peat fuel in Canada and numerous enterprises were started during a period of several years, mostly with a view to the manufacture of peat briquettes.

The serious fuel shortage with which Canada was confronted in 1917, especially in Ontario and Quebec, led to the most renowned peat fuel project in Canada to date. This was conducted at Alfred, Ontario, by a Joint Peat Committee appointed in 1918 and financed equally by the Federal and Ontario governments. Its purpose was to conduct an investigation concerning ways and means of converting Canadian peat into marketable fuel. The main objective was the development of machinery to carry out the several stages of peat fuel production by the air-dried method. This was considered to be the only economical peat manufacturing process as the cost of labor had escalated following the First World War.

Although the production of air-dried peat mechanically during the course of the project was technically successful the economical production was aggravated by trends in production and costs of other fuels. A comprehensive report on the Alfred project, published in 1926, formed the basis for technological innovation in the peat industry in later years in Europe and North America.

At the beginning of 1923 the Committee indicated that it was satisfied that the research work required for the development of a successful peat manufacturing plant had been completed and it was expected that the private sector would continue the plant operation. The Dominion Fuel Board, responsible for monitoring Canada's fuel supplies at the time, reported that it was of the opinion that peat should be utilized to supply a part of the fuel needs of central Canada and, "if the results accomplished last year (1922) at Alfred are not sufficient to induce private capital to engage in the production of this fuel, further encouragement should be given the industry by the government concerned." Later a private company was formed and an active manufacturing operation began in 1925. In 1927, however, the plant was turned over to the federal government for a commercial demonstration of the manufacture of peat fuel. Also in 1927 peat humus suitable for soil dressing was shipped from the Alfred bog to determine its marketability. This was apparently the beginning of the "peat moss" industry in

Canada. The "peat moss" was used for animal litter, soil dressing, mull, and fertilizer. A combination of international circumstances, ingenuity, and good luck promoted this undertaking to the basis of Canada's currently successful peat moss industry.

The on-again, off-again cycle of interest in peat as a source of energy has been allowed to follow the economic supply patterns dictated by foreign fuel sources. Unlike oil, gas, and uranium, which have been blessed with massive government support for discovery and development, Canada's peat resources, which in magnitude outstrip the above-mentioned energy resources, have received little or no attention during periods in which there was little or no concern about the energy supply. Historically, in Canada peat has only received significant attention during periods of crises related to energy supply. Development of the resources is expected from private enterprise and this has just not happened.

THE PEAT PROGRAM

Origin

The 1973 oil embargo by OPEC again subjected Canada to an even greater fuel crisis than that of 1918-25 and once again interest in our indigenous peat resources was spawned. Once again in the early 1980's the potential of these resources was realized by the federal and provincial governments and in 1982 a research and development program evolved under the umbrella of the interdepartmental Panel on Energy Research and Development (PERD) of the federal government.

Structure/Mechanism

To satisfy envisioned initiatives of using peat in Canada for energy and chemical applications requires rationalization and definition of the peat resources whereby those potential resources can be delineated within land resource management and environmental constraints. The evaluation of peat as an alternative organic feedstock for energy production systems, the manufacture of a host of industrial carbon-based products, and the realization of the land-use potential of cut-over peatland imply an increasing investment for research into peatland management and peat technology.

To provide a mechanism to promote these initiatives a Peat Program was established and modest funds were allocated by the federal government to several Departments through an interdepartmental Panel on Energy Research and Development. The Peat Program management was assigned to the National Research Council's Division of Energy and the Program functioned under the envelope of Renewable Energy. As peat may be considered an old biomass, and by operating the Peat Program in close proximity to the Bioenergy R&D Program, activities related to peat conversion were possible with only a minimal additional economic expenditure. In addition to buying research through contracts (extramural), modest in-house (intramural) research, particularly directed to new carbon/chemical products development and test standards, was carried out at the Atlantic Research Laboratory of NRC. This research took advantage of the relative ease of dovetailing peat carbon/chemical research with the on-going coal pyrolysis/testing program and recognized peat's other side, i.e., geologically speaking, a young coal.

The activities of the Peat Program were not established in isolation but by consensus derived by a consultative process. This process involved a Peat Forum, constituted of performers from various federal government departments with interests in peat and peatlands, including Agriculture Canada, Environment Canada, NRC, and DNA. It also involved the Canadian National Committee of the International Peat Society (CNC-IPS) whose secretariat was located at NRC and whose members represented the widely varying interests

of the Canadian peat community; and it interfaced with provincial agencies through liaison with the Peat Technical Working Group of the Interprovincial Advisory Committee on Energy (IPACE). The Peat Program also responded to international initiatives through cooperation within the International Energy Agency (IEA).

Objectives

Research efforts were directed to resource definition and to the development of new mining and processing technologies and strategies within acceptable environmental constraints and land management policies. Such technologies that could be expected to permit more or less year-round peat resource development were promoted with a view to production of feedstocks for energy and chemical production along conventional lines. The development of new products to take advantage of special attributes of peat, such as reactivity, ion exchange, and binding capacities constituted another objective of the Peat Program. Assessment of environmental impacts of peatland development was of high priority and environmental protection criteria and abatement technology to alleviate such impacts were researched. As well, reclamation strategies for mined peatland were addressed.

Activities/Achievements

The research and development emphases of the Peat Program were directed to peat resources evaluation; wet peat mining technology and systems; processing, including dewatering and combustion; environmental concerns; carbon/chemical product development; and testing and standarization.

A number of reports, including those listed in the Bibliography, were published. For the most part these are contractors' reports. Others are Symposia Proceedings in which NRC played a leading role through the Canadian National Committee of the International Peat Society. These Proceedings in many cases were used as a technology transfer vehicle for ongoing R&D of the Peat Program.

Synopses of the major activities of the Program follow, and the results of a number of the more mature research and development projects are presented in the Appendix through Executive Summaries, Abstracts, or Conclusions, and Recommendations as contained in the contractors' reports. Complete reports as listed in the Bibliography are available from Publications Sales and Distribution, NRC, or from CNC-IPS in the case of Symposia Proceedings.

Peat Resources Evaluation

This activity was championed by Agriculture Canada (Land Resource Research Institute) and Environment Canada (Canadian Forestry Service).

By 1985 a peatland inventory methodology was developed and ensured uniform, systematic, and accurate data collection in the various areas of Canada, including the Newfoundland-Labrador region, the Prairie region, the St. Lawrence Lowlands region, and the Pacific Coast region. In conjunction with the field studies a computerized Wetlands Registry was developed and this will allow storage and evaluation of peatland data generated by future inventory projects. The use and promise of radar imagery in inventory was explored.

The first level inventory estimates Canada's peatlands to cover an area of $111\ 328 \times 10^3$ ha, representing 12% of the total land area. A wide range of peatland types occur in these peatlands. There are approximately 335×10^9 t of dry peat or 507×10^9 t with 50% moisture. The energy value is 6.7×10^{21} J. The energy equivalent of southern minable peatlands is $\sim 2.7 \times 10^{21}$ J, a magnitude comparable to Canada's coal resources.

Peat Mining

Wet peat mining constituted a major activity of the National Research Council under the Peat Program.

To realize peat production that is independant of solar drying conditions, wet mining peat at various production levels and from drained and undrained deposits is believed to hold most promise for large-scale peat production in Canada.

Currently almost all significant production of peat is by dry mining methods, i.e., removal of peat from a drained bog followed by solar drying of the extracted or disturbed peat layer on the bog surface. Solar drying limits the production of peat to about a four-month production season.

Wet peat mining as practised for some 40 years in the USSR involved the mining and pumping of peat in the form of a slurry to a drying surface and subsequent solar drying. The wet peat mining systems advanced by NRC utilized slurry mining, pumping, and transport to be followed by in-plant processing/dewatering that would permit independence from solar drying and extension of the production season to 9-10 months for most of Canadian peat production locations.

A technical assessment of the various mining methods practised internationally was first completed and the compatibility of wet mining systems with various peat processing scenarios and feedstock requirements was evaluated. The development and demonstration of a wet mining system best suited to Canadian fuel peat production, with cost information including capital requirements and operating costs followed, was accomplished through

multiphase contractural arrangements in which the New York State Energy Research and Development Authority (NYSERDA) was an equal partner.

Phase 1 developed methods for calculating the main peat slurry pumping parameters based on an intimate knowledge of peat characteristics, including the degree of decomposition and peat slurry viscosities.

Phase 2 involved a review of the various designs of peat slurry pumps, preparation of a new design, and pump fabrication. The construction of the prototype peat slurry pump/macerator by Allis Chalmers Canada Inc. was completed in 1985 and subsequent shop tests with water proved that the pump exceeded the design requirements of 2000-4000 USGPM. The peat slurry pump has several unique features including an external deflector to repel roots, stumps, and other debris and an internal macerating unit to prepare the peat in its most suitable form for pumping, transport, and fuel production.

Phase 3 was a "run-in" field test of the peat slurry pump/macerator in New York State during the summer of 1985 in which the performance of the pumping and pipeline system operating in peat slurry was evaluated. In addition, the test evaluated the effectiveness of preparing slurries using hydromonitors as well as the maceration effect on pumping and pipeline transport. The pump demonstrated capability of handling slurries up to 8% solids.

Phase 4, being conducted at the time of writing, is an industrial scale field demonstration of the prototype pump and the mining and transport system at a peat bog in Ontario. Full instrumentation of this test will permit technical and economic assessments of the wet peat mining system.

In addition to significantly increasing the length of the production season, wet peat mining would require significantly less active mining area, could operate without drainage, and could operate in woody deposits considered unminable with current technology. It is expected that environmental problems would be alleviated by wet peat mining. Peat slurry processing systems being developed that largely eliminate the requirement for solar drying to obtain a peat fuel product of suitable moisture content show considerable promise. In the past, wet peat fuel mining was ultimately dependent upon solar drying of the peat. In addition to the improved mining technology resulting from the peat slurry pump/macerator development the promise of technical/economic breakthrough in peat processing augers well for the future of wet mining peat compared to the past track record.

Peat Processing/Dewatering

As noted above, peat wet mining and dewatering processes are natural partners in the development of modern peat fuel technology. Economic failure

of past wet peat mining projects is almost totally due to the dependence on solar drying of the peat involving excessive labor costs for handling and transport of the peat. For this reason, the Peat Program has put top priority on the development of processing/dewatering systems. There has been considerable effort in recent years in the development of peat processing technology which accepts peat in a slurry form. A number of private companies offer technology, some reported to be at a state of commercial readiness, for processes accepting peat slurry feedstock, and considerable research and development is ongoing in the United States, Canada, and Europe on novel methods and improvements for peat processes and dewatering. A NRC contracted state-of-the-art review of current technology accumulated technical and economic process plant data in sufficient detail to allow recommendations for conceptual design of system(s) for dewatering and further processing of fuel peat. The design of a system unique to Canadian conditions with respect to peat and peatland types or a hybrid system that incorporates the best in existing technology was the initial target.

The Peat Program supported work at Université de Sherbrooke involving high speed heating, compression, and pressure release effected at comparatively low severity in terms of combination of temperature, pressure, and residence time. This initiated selective breakdown of the peat slurry components of varying hydrophilic structure that could be subsequently dewatered in a pressure filtration stage. A patentable dewatering process resulted from this work.

Contracts with McGill University supported research on the use of microbial products such as polymers, surfactants, and enzymes, to enhance the mechanical dewatering of peat. The most effective of the biological compounds was the polysacharide Chitosan. It dramatically increased the effectiveness of mechanical dewatering and it resulted in improvement of the quality of the expressed water. Although this project was suspended by termination of the Peat Program and before development that could indicate the economic potential of the process, certain applications were deemed to be potentially patentable.

It has been shown that micro-organisms can be used to treat carbonaceous materials dissolved in expressed waters. High BOD values in these waters can be used as the basis of fermentation media to grow micro-organisms which produce valuable products. Dewatering agents such as Chitosan can thus be synthesized.

Peat combustion technology was advanced under the Peat Program by means of a number of projects, the most significant being successful development of techniques of feeding and combusting peat in a two-stage gasifier/combustor, the Lamb-Cargate Wet-Cell Burner. Prior to termination of the Peat

Program plans were in progress for the temporary conversion of a commercial scale wood waste burning unit to test burn peat.

Environment

Projects under this activity were sponsored mainly by the Environment Protection Service of Environment Canada (environmental protection criteria), the Land Resource Research Institute of Agriculture Canada (reclamation strategies), and NRC (wildlife distribution and peatland conservation). Concerns for the environmental effects of peatland exploitation were addressed through the (a) development of environmental protection criteria and technologies applicable to peat extraction, processing, combustion, and conversion processes; (b) development of reclamation strategies for mined (cutover) peatland; and (c) determination of wildlife distribution and habitat in peatlands.

Significant progress was realized in identification of the pollution potential for mining and processing/dewatering of peat for energy - including the disruption of extensive habitat, effects on hydrology and hydrogeology, particulate problems in drainage and mining, and fugitive dusts relative to dry mining. A model developed to assess the ecological impact of peatland development will aid in future assessments of potential environmental disturbances in peatland exploitation.

Product Development and Standardization

Modest laboratory space was made available at NRC's Atlantic Research Laboratory, Halifax, for intramural research under the Peat Program. Between January 1983 and March 1985 the laboratory initiated carbon/chemicals research and development and played a participating role in the activities of international standards organizations and the International Energy Agency.

Plans were advanced for the construction and operation of a process development unit (PDU) to develop a novel thermal/chemical pretreatment process for wet-mined peat slurries. This process was to be based on a new concept for heat exchange design in combination with low temperature operation and the addition of low cost surface active agents. A patent application on the process was prepared. Final assembly and commissioning of the system was aborted on notification of termination of the peat research program.

A state-of-the-art assessment of the production of peat carbon products concluded that the use of peat cokes as a reducing agent is a promising application. On the other hand it was concluded that the domestic activated carbon market is too small and segmented to support peat-based activated carbon manufacture.

Results of experimental work on the anaerobic fermentation of peat pressate for the production of methane were promising with indications that there are adequate levels of macro- and micronutrients in the Wetox^{R} pressate for the process. It was concluded that the raw biogas should be an excellent fuel for thermal drying of the peat-derived fuel with sufficient quantities available to raise the solids content of mechanically dewatered peat from 50 to 62%.

Work on the use of peat extracts for solvent production by fermentation also was encouraging.

INTERNATIONAL PARTICIPATION

International Peat Society

The International Peat Society (IPS) is a scientific and technical society for the study of peat and peatlands. Its principal aim is to promote international understanding and cooperation on all matters concerning the study and utilization of peatlands, bogs, peat, and related materials with a view to advancing progress in the scientific, technical, and economic fields.

The Canadian National Committee of the International Peat Society (CNC-IPS) was formed to promote and encourage the mutual improvement of its members through the exchange of information and ideas; the coordination and dissemination of scientific, technical, and economic information concerning peat and peatlands; the organization of and participation in national and international symposia, field excursions, and visits to centres of research, production, and utilization; the establishment and maintenance of contacts with members and organizations working in related fields; and research concerned with peat and peatlands.

The Peat Program through support to CNC-IPS promoted liaison with the international community of engineers, scientists, and industry. This support was expressed by maintenance of the functions of the Secretariat and funding activities of a number of symposia and workshops held across Canada more or less annually.

International Energy Agency

Canada is a participant with some 20 other countries in an International Energy Program which was developed in the wake of the 1973/74 energy crisis. Administration of the Programme is carried out by the International Energy Agency (IEA), which was established in Paris as an autonomous body within the Organization for Economic Cooperation and Development. Participating countries agreed to carry out national programmes of energy research development and demonstration and to undertake cooperative activities including jointly-financed programmes and projects in energy RD&D.

In 1984, Canada, Ireland, Finland, and Sweden agreed to take part in the establishment and operation of a continued Programme of Research, Development and Demonstration on Peat Production and Utilization. The International Energy Agency recognized the Programme as an important component of international cooperation. Canada participated in the work of Annex 1 (Task 1) of the Programme identified as cooperation in assessment, planning, and implementation for research, development, and demonstration on

peat production and utilization. The first phase of the task was to review the status and potential of technology and recommend research related to production of milled and sod peat, fundamentals of dewatering, new dewatering techniques, peat classification and standards, and information exchange.

Canada's lead responsibilities were exercised through NRC, as operating agent, and the Peat Program, which dealt effectively with Subtask II, identified as Fundamentals of Dewatering. Initially a contract was used to review the status of research in dewatering of other materials and ascertain the relationship to peat dewatering. This was followed by a Workshop at Rivière-du-Loup, Quebec, at which leading world scientists discussed water/peat relationships and retention mechanisms. A future research strategy was provided in a report to the IEA.

Canada's participation in the IEA peat programme was terminated in 1985.

PERSPECTIVES

Since 1982 the Peat Program has provided direct support to peat energy and chemicals research and development across Canada. The first phase of a planned five-year program to be completed in 1987 was terminated half-way through its mandate when funds were eliminated in 1985. The Program was the only federal government R&D program specifically and directly related to peat and therefore its demise left a vacuum with respect to a highly valuable potential resource.

As no significant peat R&D program existed in Canada since the 1920's the first years of the Program were mainly devoted to bringing Canada "up to speed" after many years of neglect of peat knowledge and technology compared to other countries in the industrial world. In that respect the immediate objectives of the Program were realized as the know-how in this country advanced from relative obscurity to a level at which our scientists and engineers were sought out by developing countries to assist in industrial projects in those countries, notably in Africa, Central America, and Asia. Indeed, respect was gained from other industrial countries with a long history of scientific and technical achievements and industrial application with peat. In this respect, the Peat Program played a significant role of which Canadian authorities can be proud. When the modest budget as presented in the Introduction is considered in this context it becomes apparent that the economic and technical pay-back has already been achieved.

The Peat Program was one response to a perceived energy crisis; in the respect that the knowledge of Canada's conventional energy resources was only available to potential exploiters, the crisis was real. When the crisis evaporated the interest in and support of the Program waned and most of the activities that were initiated in 1982 or later were terminated in 1984 or 1985. The time frame was obviously too short to develop mature reseach projects, in most cases.

National Policies for Peat Research and Development

Experience in other countries has shown that research and development in the use and applications of peat and peatlands progresses with greater consistency when supported by official policies and well-defined strategies and goals (Nicholson, *Peat Policies and Activities in Canada*, NRC 24353). National energy policies in Ireland, Finland, and Sweden have been instrumental in encouraging the development of organized peat R&D strategies. It is clear that in Canada a national peat policy framework or strategy is needed to guide development and an application of specific policies to peat issues. As well, provincial resource management policies for peat development and peatland use are required to ensure that the multiple-use nature of peatlands is recognized and the wisest use is made

of peatlands. It is therefore important that a clear federal government policy be established with respect to peat R&D and that the provinces consider establishment of interdepartmental committees to provide coordination and communication of peat R&D activities.

Peatland Resource

The actual resource potential of peatlands incorporating the requirements of applicable resource sectors should be assessed. The regional uniqueness and development potential of peatlands need be considered.

The resource inventory conducted under the Peat Program from 1982 to 1985 was a significant achievement that because of a rationalized methodology permitted confidence nationally in first level resource data. At the federal government level an appropriate posture would allow update of the methodology, maintenace of the Wetlands Registry, and increased confidence in the data towards measured resource levels regionally. Such information available to governments would allow rapid start-up of utilization should these resources be required to counter future energy shocks.

Mining

The Peat Program made a significant technical contribution towards alleviating the problems of seasonal peat operations through development of a wet mining system. There are, however, many unanswered economic questions related to this new technology. The R&D in this category was not sufficiently mature and there is not modern cost-based experience to draw on to indicate the economics of the wet peat mining system and the peat slurry pump operations in particular. A continuing industrial scale demonstration project is required to evaluate all economic factors, including capital and operating costs, seasonal restrictions, environmental impacts, and product suitability for various feedstocks. Finland has been very successful in its approach to equipment development whereby the government plays a leading role in support of field trials of "homegrown" equipment.

Mindful of the likelihood that in the near and medium term any peat use for energy would likely be of small scale and regionally resource based as opposed to national projects on a mega-scale, it is essential to scale peat slurry pumping and transport systems to this need, as has been realized in dry mining, particularly using peat sod cutting and extrusion machines.

Dewatering/Processing

As mentioned above, the advantages of using wet mining systems in peat production can be realized through the use of peat processing and

dewatering systems that result from research demanding low energy input units.

Promising technology is at hand that in some cases requires only scale-up pilot plant testing and economic evaluation to get to industrial application. The unique processes at McGill University and Université de Sherbrooke, involving biological compounds to enhance mechanical dewatering and the low energy/low severity processing of peat slurry to fractionate and solubilize the carbohydrate fraction, respectively, are at that stage of development and hopefully will be continued by alternate funding arrangements.

Product Development - Carbon/Chemicals

Although market analysis of carbon/chemical products indicated a mature market for activated carbon, other areas of research such as biogasification yielding methane, carbon for use as a reductant, and densified fuel products such as briquettes, fire logs, and pellets show early promise and could be developed to small, regionally based industries.

Significant use of peat and peatlands in Canada, indeed in North America, have been confined to horticulture, agriculture, and silviculture. The unpredicted energy costs stability and reduction have slowed or halted interest in peat energy. Possibilities for chemical and biochemical products from peat feedstock have been unveiled through the R&D activated by peat's energy potential. Options for peat related to higher value added organic products have been opened and indeed an energy by-product could well accompany the production of chemicals. Energy-motivated research on peat slurries which produced a low-energy means of separating water soluble and easily hydrolysable substances is the basis of unlimited possibilities for biochemical fermentation and chemical conversions. Economical dewatering of peat offers more potential for extraction of bitumens from partially dried peat as the starting point for a host of other products - waxes and resins.

Thermochemical conversions including gasification and methanol synthesis, pyrolysis, and liquefaction offer potential for production of basic chemicals and further upgrading to a variety of chemical products.

BIBLIOGRAPHY

1. Proceedings Canadian Peat Symposium, Fredericton, New Brunswick, 1979. 100 pp.

2. Proceedings Symposium on Peat - An Awakening Natural Resource, Thunder Bay, Ontario, October 26-28, 1981. 426 pp. ISBN 0-7743-7846-8.

3. Proceedings of Symposium 82 on Peat and Peatlands, Shippagan, New Brunswick, September 12-15, 1982. 582 pp. ISBN 0-660-52102-4.

4. Proceedings Symposium 83 - Energy from Peat, St. John's, Newfoundland, September 18-22, 1983. 237 pp. ISBN 0-9692186-0-5.

5. Proceedings of Symposium '85 - A Technical and Scientific Conference on Peat and Peatlands. Part 1: Peat and Peatlands-Resources and Development, Rivière-du-Loup, Quebec, June 16-20, 1985. 550 pp. ISBN 0-9692186-1-3.

6. Peat and Water: Aspects of Water Retention and Dewatering in Peat (EASP, London) (in press). This monograph represents Part 2 (Workshop) of the Proceedings of Symposium '85, Rivière-du-Loup, Quebec, June 16-20, 1985.

7. Proceedings of a peatland inventory methodology workshop. LRRI/NFRC.

8. Kesmark Ltd. Study of the technology and costs associated with dredging and overburden clearing operations for the recovery of peat. National Research Council of Canada, Ottawa, Ontario. NRCC No. 20599.

9. ADI Ltd. Report on a study on the biogasification of peat. National Research Council of Canada, Ottawa, Ontario. NRCC No. 20600.

10. Washburn & Gillis Assoc. Ltd. Survey of literature on the assessment of the pollution potential of the peat resource. National Research Council of Canada, Ottawa, Ontario. NRCC No. 20755.

11. Remotec Applications Inc. The use of impulse radar techniques for depth profiling of peat deposits. National Research Council of Canada, Ottawa, Ontario. NRCC No. 20982.

12. J. Collins. A peat research directory for Canada. National Research Council of Canada, Ottawa, Ontario. NRCC No. 21000.

13. IEC Beak Consultants Ltd. Fish and wildlife use of peatlands in Canada. National Research Council of Canada, Ottawa, Ontario. NRCC No. 21238.

14. Washburn & Gillis Assoc. Ltd. Identification of the pollution potential of the harvesting and preutilization processing of peat as an energy commodity. National Research Council of Canada, Ottawa, Ontario. NRCC No. 22858.

15. Monenco Ontario Ltd. Pollution potential of peat combustion, liquefaction and gasification. National Research Council of Canada. NRCC No. 22859.

16. John Sheppard. The Technical Research Centre and the Peat Industry in Finland. National Research Council of Canada, Ottawa, Ontario. NRCC No. 23014.

17. André Marsan et Associés/Conseil Economique d'Alma et du lac Saint-Jean. Essais combustion boudins de tourbe provenant des tourbières du lac Saint-Jean/Combustion tests on sod peat from peat bogs of the Lac Saint-Jean Region, Quebec. National Research Council of Canada, Ottawa, Ontario. NRCC No. 23015.

18. Monenco Ontario Ltd. An evaluation of alternative wet peat mining systems. National Research Council of Canada, Ottawa, Ontario. NRCC No. 23016.

19. I. Ismail, Montreal Engineering Company Limited. Process evaluation and conceptual design of plant based on a technical and economic assessment of peat dewatering and peat fuel processes - Phase 1. National Research Council of Canada, Ottawa, Ontario. November 1983. NRCC No. 22911.

20. Washburn & Gillis Associates Ltd. Evaluation of data from 1982 sampling program of potential pollutants in water and peat samples from three peat bogs in Canada. National Research Council of Canada, Ottawa, Ontario. NRCC No. 23214.

21. Ontario Research Foundation. Wastewater characteristics of five peat dewatering processes. National Research Council of Canada, Ottawa, Ontario. NRCC No. 23758.

22. Ontario Research Foundation. Wet oxidation of peat liquid and solid fractions for environmental and energy studies. National Research Council of Canada, Ottawa, Ontario. NRCC No. 23806.

23. ADI Ltd. Anaerobic fermentation of ORF Wetox peat pressate for the production of methane. National Research Council of Canada, Ottawa, Ontario. October 1984. NRCC No. 24083.

24. J. Collins and J. Webb, Northern Design and Crafts. Update of a Peat Research Directory for Canada. National Research Council of Canada, Ottawa, Ontario. October 1984. NRCC No. 24099.

25. K. Clarke-Whistler, W.J. Snodgrass, P. McKee, and J.A. Rosell, IEC beak Consultants Ltd. Development of an innovative approach to assess the ecological impact of peatland developments. National Research Council of Canada, Ottawa, Ontario. Ecological Background and Preliminary Model Development. November 1984. NRCC No. 24129.

26. FMC Ltd. Use of clostridium butylicum for the production of butanol and acetone from peat pressate. National Research Council of Canada, Ottawa, Ontario. NRCC No. 24130.

27. CUS. Les actes du Symposium sur la tourbe et les tourbières. Shippigan (N.-B.). 12-15 september 1982. National Research Council of Canada, Ottawa, Ontario. January 1985. NRCC No. 24134.

28. C. Tarnocai, Agriculture Canada. Peat resources of Canada. National Research Council of Canada, Ottawa, Ontario. October 1984. NRCC No. 24140.

29. D.G. Cooper, C.N. Mulligan, and D.W. Pillon, McGill University. The use of microbes in the dewatering of fuel grade peat. Part I. National Research Council of Canada, Ottawa, Ontario. May 1984. NRCC No. 24151.

30. J. Philip Nicholson Policy and Management Consultants Inc. (Ottawa). Peat policies and activities in Canada. Vol. I: Highlights. National Research Council of Canada, Ottawa, Ontario. NRCC No. 24353. Vol. II: Details. National Research Council of Canada, Ottawa, Ontario. December 1984. NRCC No. 24354.

32. I.G. Rowe, Lamb-Cargate Industries Ltd. Development of the Lamb wet-cell burner for energy from New Brunswick peat. National Research Council of Canada, Ottawa, Ontario. April 1985. NRCC No. 24430.

32. A.L. Burwash Consulting Ltd., Crozier Information Resources Consulting, and D.W.S. Westlake. Final report on investigation of transferable technology for application in peat dewatering research. National Research Council of Canada, Ottawa, Ontario. May 1985. NRCC No. 24475.

33. Montreal Engineering Company Limited. Carbon products from peat. National Research Council of Canada, Ottawa, Ontario. April 1985. NRCC No. 24492.

34. Monenco Consultants Ltd. Development of design parameters for peat slurry pumping and pipeline transport. National Research Council of Canada, Ottawa, Ontario. May 1985. NRCC No. 25033.

35. D.G. Cooper, D.S. Glass, and D.W. Pillon, McGill University. The use of microbes in the dewatering of fuel grade peat. Part 2. National Research Council of Canada, Ottawa, Ontario. August 1985. NRCC No. 25034.

36. Monenco Consultants Ltd. Design and construction of a peat slurry pump/macerator. National Research Council of Canada, Ottawa, Ontario. September 1985. NRCC No. 25457.

37. T.E. Tibbetts. International Energy Agency Programme of Research, Development and Demonstration on Peat Production and Utilization. Annex 1: Cooperation in Assessment, Planning and Implementation for Research, Development and Demonstration on Peat Production and Utilization. Stage 1 Report of Subtask II: Fundamentals in Peat Dewatering. National Research Council of Canada, Ottawa, Ontario. January 1986. NRCC No. 25499.

38. NYSERDA/MONENCO. Peat slurry pumping demonstration project (field testing of peat slurry pump/macerator). In press.

39. Université de Sherbrooke. Solvolyse et fractionnement selectif de la tourbe/Autohydrolysis and fractionation of peat via the UdeS-NRC thermomechanical process. (In press).

40. MONENCO. A demonstration of wet (slurry) mining of a Canadian peat deposit.

41. John Sheppard. Peat Program Activities at the Atlantic Research Laboratory. National Research Council of Canada, Ottawa, Ontario. April 1985.

APPENDIX A: EXECUTIVE SUMMARIES

Appendix A contains Executive Summaries, Abstracts, Conclusions, and Recommendations of some of the more significant research and development contractors' reports prepared for the Peat Program. These are presented in the following sequence:

(1) Policies and Activities (Section A1)
(2) Resource and Inventory (Section A2)
(3) Mining (Section A3)
(4) Dewatering/Processing (Section A4)
(5) Environmental (Section A5)
(6) Product Development (Section A6)

The contents are as presented in the respective reports. The reader is urged to request the complete referenced report if more details are desired. Copies of these reports are available from

Publications Sales and Distribution
National Research Council of Canada
Ottawa, Ontario
K1A 0R6

A1 POLICIES AND ACTIVITIES

A1.1 Report: ***Peat Policies and Activities in Canada: Highlights,*** **NRCC 24353.**
Contractor: J. Phillip Nicholson, Policy and Management Consultants Inc.

J. Phillip Nicholson Policy and Management Consultants Inc. (Ottawa) have produced a two-volume report, *Peat Policies and Activities in Canada*, in response to an unsolicited proposal which identified the need for an assessment of the current status and organization of peat research and development in Canada.

The information and recommendations contained in the report are designed to assist policy makers and program coordinators in defining future directions for peat-related research and development in Canada. The report is also intended to be of use and interest to individuals and agencies in both the public and private sectors who are either actively involved in peat activities or who have an interest in peatlands and peat resources in Canada.

The results of the study are presented in two volumes, *Volume I: Highlights and Volume II: Details.*

Volume I: Highlights focuses on the current major themes and interests in peat research and development in Canada and abroad. More specifically, *Volume I* provides an introduction to peatlands which outlines the nature and extent of Canadian peatlands as well as their historical use and recent research interests. An overview of the interests, concerns, and experiences of other countries involved in peatland development is also provided.

The major portion of Volume I is devoted to a national overview of current Canadian peat issues, interests, and activities in the private and public sectors as well as a review of key policies, programs, legislation, and coordinating activities of the federal and provincial governments which are of relevance to peat research, development, and management in Canada.

Finally, Volume I provides recommendations in the areas of policies and legislation (at both the federal and provincial level); coordination and communication; research and development; international involvement; and training and education to aid in the further development and evolution of peat programs and activities in Canada.

Volume II: Details presents detailed information of the organization, objectives and nature of peat and peatland activities being carried out in the various agencies of the federal and provincial governments, as well as the private sector in Canada. It also presents the major programs, activities and research directions of seven European countries and several states in the United States. This is followed by Appendices, including a presentation of the current legislation and policies of particular relevance to peat research and development in Canada. The contents of this detailed volume form the basis upon which the highlights, conclusions, and recommendations contained in *Volume I: Highlights* have been formulated.

A2 RESOURCE AND INVENTORY

A2.1 Report: *Peat Resources of Canada*, NRCC 24140
Contractor/Researcher: Agriculture Canada

There are 111 328 × 10^3 ha of peatlands in Canada, which is 12% of the total land area. Because of the great variation in climate and physiographic situations, a wide range of peatland types occur on these peatlands. Peat materials associated with these peatlands are identified according to their botanical composition. Their physical and chemical characteristics depend on their botanical composition and the region in which they were deposited. There are approximately 3 004 996 × 10^6 m^3 or 335 × 10^9 t of dry peat or 507 × 10^9 t with 50% water content in Canada. The energy value of this peat resource is approximately 6.7 × 10^{21} J. The existing mining techniques are able to handle only the unfrozen, southern peatlands, whose energy equivalent is approximately 2.7 × 10^{21} J, similar to that of the coal resources of Canada.

A2.2 Report: *The Use of Impulse Radar Techniques for Depth Profiling of Peat Deposits*, NRCC 20982
Contractor: Remotec Applications Inc.

With the growing interest in peat as an energy fuel, the need for better inventories of this resource becomes increasingly important. Although conventional imaging sensors can provide information on the areal extent of peatlands, depth measurements must still be taken in the field in order to estimate the volume of material present. A recently completed program conducted in eastern Newfoundland suggests that impulse radar systems can provide depth information and volume estimates comparable to those obtained with manual measurement techniques, in much less time and with considerably less effort. When used in a profiling mode, the impulse radar records provide a more detailed portrayal of the deposit bottom and indicate the presence of snags and internal interfaces within the peat.

Ground-base data were acquired in mid-summer and early fall using 80 and 400 MHz radar systems towed behind an all-terrain vehicle. Airborne data was collected using 80 and 120 MHz systems mounted beneath a helicopter in summer, fall, and winter. In the case of ground-based profiles peat thickness of up to 8.1 m was clearly visible; no deeper deposits were situated within close proximity of the base of operations, which prevented determination of the maximum detectable depth. The airborne profile data were generally poorer in quality and were limited by reflections from the peat surface. However, depths of up to 4.8 m were successfully profiled from an altitude of 1.5 m. Point soundings made when the helicopter was on the

surface of the deposit yielded quite strong returns and would presumably be as successful as ground-based measurements for deeper thicknesses of peat. No significant seasonal variations were observed.

Impulse radar techniques should be able to contribute to all levels of peat resource assessment. However, since they do not appear to provide any information on the quality of the peat material, they would seem to be particularly useful for reconnaissance level surveys. In most cases, the use of a single propagation velocity for all deposits would seem to be justified, but in some instances it may be necessary to determine the velocity at each site in order to minimize absolute errors. Although the technique can now be used operationally, further data collection would provide a better understanding of the variability of impulse radar propagation in peat. Additional research is needed in order to develop a system suitable for airborne profiling.

A3 MINING

A3.1 Report: *Study of the Technology and Costs Associated with Dredging and Overburden Clearing Operations for the Recovery of Peat*, NRCC 20599

Contractor: Kesmark Ltd.

Over many years, cutter-suction dredging has been recognized as an economical means of excavating and transporting large quantities of silt, clay, sand, gravel, and stone. These dredges consist of a large floating hull, supporting a rotating cutting head which, when lowered into the water, excavates a soils bank to 10 to 20 m in depth. The rotating cutter produces a soils-water slurry of 10% to 30% solids by weight, which is sucked into an on-board pump, which in turn forces the slurry into pipelines to carry it distances of as much as 30 km.

In eastern Canada, large volumes of peat have been moved by cutter-suction dredge, but this is normally as an admixture with mineral soils. Cutter-suction dredging of peat alone is quite a different exercise.

The structure of peat is unlike that of mineral soils, the specific gravity being less than half. The cell structure is such that it holds large quantities of water than can only be released with the application of heat. Such physical applications as grinding, squeezing, or centrifuging reduce the water content but little. In short, when one pumps peat, one is pumping 10 to 20 weights of water per 1 of peat, whereas, with clay for example, the ratio could be 3 to 6 weights of clay per 1 of water. At the same time, pumping flexibility is limited to a maximum slurry thickness of 10% peat, by weight.

Peat deposits are relatively shallow and for peat dredging purposes should be selected of greater than 2 m in depth, which occurrences will probably not exceed 6 m maximum depth. Adequate supplies of water need to be available near the peat deposit, to replace the large volumes of peat and water to be pumped out of the deposit area to be delivered to an energy recovery process plant.

In situ fuel peat varies in composition from 85% to 97% water content and, as such, deposits to be sought for dredging should be of 90% water content or less, inasmuch as a 95% water content doubles the volume that will have to be pumped. Peat as macerated by the dredge cutter is considered to be pumpable at 10% solids by weight, but some dilution at the cutter is inevitable. It is considered that a 7% or 8% slurry is deliverable to a process plant. Water levels in the dredge pond must be maintained at adequate depths to float the dredge and this probably requires dike ponding and pond water level control by additions from adjacent streams or lakes.

Peat dredging equipment must differ from that normally used. The dredge hull must be of shallow draft to minimize dredge pond dike requirements. In that peat deposits are shallow, a dredge must be capable of rapid horizontal movement. Also, the cutter must engage and cut full-time at the peat face, without loss of cutting action as the dredge moves forward or as the cutter swings from side to side. Moreover, the cutter must be vertically controllable within narrow limits to continuously cut a full face of peat and, at the same time, avoid cutting into the bottom mineral soils, which would contaminate the peat slurry. The cutter must be capable of leaving a smooth bottom without ridging and be capable of macerating roots and trees which grow in the peat or which were deposited there during peat formation. Storage surge ponds or tanks would probably be required to provide the process plant with a continuous feed at times when the dredge is inoperative, for example, while dredge pipe is being moved or repairs are being made.

To derive order of magnitude costs for a dredged delivery of peat to a process plant, three Ontario sites were selected for conceptual costing. However, there is little information available for large peat deposits in the detail necessary to perform a site-specific dredging feasibility study. As such, exploratory work has yet to be carried out. However, many large areas of peat exist in Ontario extensive and deep enough to be suitable for dredging.

Cost estimates for peat dredging, based on the conceptual basics described in this report, indicate that, with a 20-year dredge life, 1981 dredging costs would be in the order of $3.00 to $5.00 per dry tonne of peat, delivered to a process plant as a water slurry of 7% to 8% peat, by weight. Costs for peat, on the basis of 50% moisture, a fuel used for steam generation in Europe, would cost half that amount per tonne, delivered as a like slurry.

It is unlikely that peat dredging can be carried out in the three or four winter months, except at excessive, increased cost and as a consequence, surge or stock-piling facilities would have to be provided for that period, appropriate to the requirements of the plant. However, it should be noted that Steep Rock and Caland Mines dredged for several years in a very cold Ontario climate and consistently operated throughout the winters.

To operate a 16-in. dredge in peat at maximum efficiency, operations must proceed around the clock through the dredging season and consequently a consuming process plant would have to be of substantial size. Dredge sizes of less than 16 in. are not considered to be practical as they would be too small to macerate roots and trees and would consume excessive amounts of power and labour to pump adequate distances. Dredges of 30 in. and more

are ponderous machines and could only be considered for unusually extensive and deep peat deposits.

In summary, this study indicates that peat dredges should be capable of excavating from the deeper, more extensive deposits of fuel peat to be found, for example, in Ontario. The dredge slurries so produced are deliverable by pipelines to an energy producing process plant, preferably one which would employ wet processing.

A3.2 Report: ***An Evaluation of Alternative Wet Peat Mining Systems*****, NRCC 23016**

Contractor: Montreal Engineering Co. Ltd.

During the course of the study, considerable information on actual wet peat mining systems used previously, or in current use, was reviewed. Of particular interest was the extensive Russian experience in wet peat mining and peat slurry pumping which was practiced from about 1915 until the early 1960's, nearly 50 years. Approximately 10×10^6 t (air-dried peat) was produced annually in the USSR by wet mining methods during the early 1950's.

The Russian wet peat mining system (Hydropeat) was discontinued in the early 1960's in favour of dry mining (milled) methods. Although the system was not well mechanized the principal reasons for discontinuance were related to the drying and subsequent harvesting operations which had a high manpower requirement, many moves, and physical changes associated with the pipeline manipulation for the peat slurry spreading operation. Solar drying and harvesting were not required for the applications of wet mining investigated in the study.

Unique to this study is an attempt to discuss in detail the important characteristics of peat (moisture content, degree of decomposition, peat type, ash content, stumps content, etc.) and their effects on the various mining processes considered, including their relationship to the key peat slurry pumping parameters. For instance, the dependency of solids concentration (a key peat slurry pumping parameter directly related to output) on factors such as peat type and degree of decomposition has been discussed in detail.

In selecting wet peat mining methods for further detailed assessment, only methods which could fill certain requirements were chosen. The requirements included production of a standard quality of feedstock (for use in a processing plant for fuel production), utilization of equipment currently commercially available, effective peat recovery, etc.

The operations considered in this report were somewhat smaller scale than systems previously studied by others (e.g., recent peat dredging studies). Small-scale peat operations were considered to be about 50 000 t/a, and large-scale operations up to 1×10^6 t/a (all air-dried peat at 50% moisture content).

Four wet peat mining methods were selected for each case, i.e., for the undrained and drained peatland situations. The various methods were described and the advantages and disadvantages of each were discussed. Final selection of the most suitable method for each case (i.e., for undrained and drained peatland) took into consideration the following mining and feedstock requirements:

- mining: peat and peatland characteristics (peat type, peat quality, size of deposit, moisture content, pet depth, degree of decomposition, ash content, stumps content)
- feedstock: quality of the peat slurry as a feedstock to the process plant (optimum solids content, maximum pumping capacity, minimum pipeline pressure losses, high quality slurry, preparation characteristics)

For the final selection of a suitable method for each case (i.e., undrained and drained peatlands), a number of factors (15) were listed (technical, economic, environmental, etc.) and given a selection of a mining method. The various methods were then given a score for each factor resulting in a final ranking of the methods. The method which received the highest ranking was selected for further economic analysis.

In the case of the undrained peatland, the preferred method, selected as described above, was considered to be the bulk peat excavation by Amphidredge method. For drained peatlands, the slurry pump dredge system received the highest ranking.

For the wet peat mining of undrained peatlands the bulk peat excavation by Amphidredge appeared to have some distinct technical advantages related primarily to the flexibility and maneuverability of the Amphidredge machine. The equipment is self-propelled (it walks like a turtle) and has a minimal depth of water requirement for navigation (i.e., extensive flooding of the peatland surface is not required). The current model has a backhoe mounted to carry out excavation; this tends to limit output.

The wet peat mining of drained (or partially-drained) peatlands using the slurry pump dredge system represents an attempt to take two key elements of the previous Hydropeat method (the hydromonitors and peat slurry pump) and modify and upgrade the equipment and combine it with other North American technology to produce a successful high capacity mining system. It was

known that hydromonitors are effective on peat and that the specially-designed peat slurry pump could produce favourable peat slurry characteristics to achieve optimal peat slurry pumping conditions. It was also necessary to locate a craft for mounting the equipment which could operate under conditions of minimal draft (e.g., large Amphidredge or hover barge) to maintain the required solids content and operate on drained or partially drained peatland.

To achieve optimum peat slurry pumping conditions (e.g., maximum pumping capacity, maximum pumping distance, minimum pipeline diameter) factors such as solids content, viscosity, flow velocity, and pressure losses are considered. It is possible to determine these parameters using information and peat slurry pumping calculating methods previously developed in the USSR. A certain amount of correlation between European and Canadian peat data collection systems, and the development of new laboratory methods, is required to meaningfully utilize the existing European peat slurry pumping data.

For actual wet peat mining operations, it is recommended that a special peat slurry pump of suitable construction be manufactured which can achieve the high quality slurry preparation characteristics (i.e., the required degree of grinding, cutting, and mixing of the peat slurry) as well as pumping the peat slurry a maximum distance.

Preliminary cost calculations were performed on the two mining methods considered best suited for undrained and drained peatlands. A levelized unit cost (including capital and operating costs) was calculated for the bulk peat excavation by the Amphidredge method (used for undrained peatland) and resulted in a cost of $30.20/t (equivalent 50% moisture content basis). Similarly, a levelized unit cost was calculated for the slurry pump dredge method and gave a result of $6.68/t (equivalent 50% moisture content basis). The annual production rates determined for the two selected cases were 50 000 and 250 000 t air dried (equivalent 50% moisture content basis), respectively.

Although mining on undrained peatland requires little surface preparation or drainage in advance of mining, especially compared to dry mining techniques, it was found that the equipment requirements for operating on the undrained peatland (bulk peat excavation by Amphidredge) resulted in a relatively high capital cost per installed unit capacity as compared to the system selected for the drained peatland (slurry pump dredge). As well, it appeared that the bulk peat excavation method selected was too small in capacity and required approximately the same size labour force as compared to the higher production slurry pump dredge method. The flexibility and maneuverability of the Amphidredge equipment on peatland surfaces appeared

impressive, and an investigation into refinements of the wet mining technique using this equipment is probably warranted.

A comparison of technical and economic factors showed certain advantages of wet peat mining methods over dry methods such as higher unit capacity, higher yield from a cubic metre of raw peat, less active surface area requirements, and less manpower. However, in the case of comparison with the milled peat method (a dry mining method), the total power requirement per 1000 t air-dried peat was higher for the wet mining methods.

Only an introduction into the field of peat slurry pumping has been possible within the scope of the study. It is suggested further investigations into peat slurry rheology be initiated, utilizing the considerable existing European information to verify the assumptions and findings of this report.

A3.3 Report: *Development of Design Parameter for Peat Slurry Pumping and Pipeline Transport*, NRCC 25033

Contractor: Monenco Consultants Ltd.

The preliminary work carried out for this study indicates that the North American peats and peatland types have the same characteristics as do the Russian. In fact, a few laboratory tests on North American samples reveal that the North American peat and peatland types fit quite well into the Russian system. Therefore it has been deduced that the correlation of North American peat and peatland types with the Russian is positive, and as well, that the characteristics of the similar peat types are close. However, due to the lack of a sufficient statistical background, the positive results given in Part 3 must still be regarded as preliminary and will have to be confirmed by a larger sample population and practical pumping tests.

To our knowledge, all recently published work which includes information on the degree of humification (decomposition) of North American peats uses field methods (such as von Post) for their determination. For purposes of the present study, it was necessary to duplicate the USSR laboratory method for degree of decomposition testing in order to obtain comparable results, since all the Russian degree of decomposition data was determined by this method.

The laboratory method was successfully applied to Canadian and New York peats, and the information obtained on this peat characteristic can be used in the design of wet peat mining systems using the "hydropeat" type of equipment.

It is possible to compare the degree of decomposition and viscosity tests on North American and USSR peat types (with similar qualitative characteristics) since the testing was carried out using the same design of laboratory equipment and the same procedures in both cases.

The following viscosity correlations were determined from the laboratory testing:

(a) between the qualitative peat characteristics (peat type, degree of decomposition, ash content) and slurry viscosity;
The various types of peat have their own unique viscosity values depending on their composition (chemical and physical) which is determined by the peat forming plants and the environment in which the peat is formed. The highest viscosity results were obtained on peats with low degree of decomposition, such as "sphagnum medium" or "sphaghum mixed" with average 10-15% degree of decomposition (or von Post H2-H4). The viscosity decreases with increasing degree of decomposition. The laboratory testing program did not include studies of the relationship between ash content and peat viscosity since the effects of ash content and degree of decomposition on peat viscosity are interdependent. The correlation between North American and USSR peat slurry viscosity values for peats with different qualitative characteristics were investigated. A solids concentration range of 4% to 6% (solids by weight) is expected for slurry pumping of Canadian peats using "hydropeat" equipment. The results should be regarded as preliminary since sufficient statistical data have not been accumulated and practical pumping tests have yet to be carried out.

(b) between peat slurry solids content and viscosity;
The viscosity of a peat slurry decreases in proportion to decreasing solids content, and vice versa.

(c) between effects on maceration of peat slurry and peat slurry viscosity;
The viscosity of a peat slurry decreases with increasing degree of macertion, i.e., the viscosity will decrease when the amount of "processing" of the peat slurry is increased. It appears that for high viscosity peats (highmoor peat), the influence of maceration is more significant than for the less viscous (lowmoor peat) peat slurries.

(d) between peat slurry temperature and viscosity;
The viscosity of a peat slurry decreases with increasing slurry temperature, i.e., the lower the temperature of the slurry, the higher its viscosity.

Prior to carrying out the present work, an intensive review of existing information on peat slurry rheology showed virtually no information existing in the west, particularly related to actual peat slurry pumping system design. A 1982 engineering feasibility study on wet peat mining carried out by a major engineering firm actually assumed that peat slurry would behave as a pulp and paper slurry, and based their subsequent extraction system design on this assumption. In contrast, wet peat mining by the "hydropeat" method had been carried out for many decades in the USSR, and it was determined that the information available from this source would be a useful starting point for study of potential wet peat mining systems suited to North American peat and peatland conditions.

Methods of calculating the main peat slurry pumping and pipelining parameters (such as solids concentration, pump capacity, pipeline length, pipeline diameter, system resistance) are presented based on the previous USSR information. The methods take into account the dependency of the var- ious peat slurry pumping parameters on the peat characteristics (peat type, degree of decomposition, ash content, etc.). As well, a system optimization calculation was made which takes into consideration both the hydraulic and mining aspects, such as the dilution caused by the hydromonitors in breaking down the peat face and required for flow of solids to the pump, factors which compete against the need to maintain high slurry concentration for maximum peat production. Two computer programs were developed by Monenco to increase the speed and accuracy of the computations and example calculations are included in the report.

The calculating method includes the pumping characteristic of the "hydropeat" peat slurry pump/macerator, which was specially designed for wet peat mining applications and includes several unique features such as a macerator section and an external propeller.

An actual field pumping test is recommended (using a modified USSR style design of peat slurry pump) to check the calculating methods for the peat slurry pumping system design. Solids concentration values achieved during the field tests can be determined and compared with the predicted values from laboratory testing and the computer calculations. Calculated values of optimum slurry solids concentration and the other pumping and pipeline parameters (pump capacity, pressure losses, pumping distance, etc.) can be compared with the actual field test results achieved from a recommended industrial-scale pumping and pipeline test system. The field tests can also serve as a check on the USSR method for predicting optimal solids content of a peat slurry using the "botanical spectrum" method.

To carry out the slurry pumping test, it is recommended to construct a peat slurry pump/macerator with similar characteristics to the previous latest USSR model.

For practical mining purposes, experience has shown that application of the "hydropeat" wet peat mining technology requires a peat deposit with a minimum degree of decomposition of 15% and a peat thickness of at least 2 m.

A3.4 Report: *Design and Construction of Peat Slurry Pump/Macerator*, NRCC 25457

Contractor: Monenco Consultants Ltd.

If a single key parameter can be indicated which experience has shown is essential for both the technical and economic success of the conventional peat slurry pumping system, it would be maceration of the peat within the slurry. Monenco studied the various aspects of wet peat mining technology for some time and considered various configurations of macerator and slurry pump, many of which were tried before in Europe. However, only the Russian peat slurry pump was a piece of proven equipment and was recommended for demonstration testing.

The uniqueness of the Russian peat slurry pump design is the inclusion of a stump and roots deflector exterior to the pump, and the cutting wheels in the macerator section of the pump, required to achieve the desired degree of maceration.

The review of previous designs of USSR peat slurry pumps, performance characteristics and materials of construction tolerances were conducted to develop a detailed design specification for the fabrication of the peat slurry pump.

Although discussions were held with a number of pump manufacturers and many novel ideas were put forward, including various configurations of macerator and/or pump, only Allis-Chalmers Canada Inc. offered to design and construct a model similiar to the previous Russian peat slurry pump.

The Allis-Chalmers pump design was based on a previous design of variable capacity fan pump (ACAP) for feeding paper stock into paper machines. The ACAP pump had a varied capacity developed by internal recirculation. This was accomplished by changes in the clearance between the open impeller and the wear plate. It was found that by increasing the wear plate clearance, the pump could pump a feedstock with a higher consistency and could also increase the air handling ability. The new design of peat slurry pump/macerator also has the capability to increase the clearance of the wear plate.

The Allis-Chalmers design incorporated the following:

- enlarged inlet/macerator to reduce the tendency to plug

- modification of the casing to a 14-in. connection matching the 14-in. macerator

- the clearance between the impeller and wear plate was set initially at 1 in. to allow enough recirculation to dislodge any entrained air bubbles forming at the impeller eye. This clearance was varied from 0.03 to 1.0 in.

- V-belt drive arrangement to allow vertical mounting of a standard 150 HP, 1800 rpm motor and a pump speed of 1000 rpm. This arrangement allowed modification of the speed which, together with the pump clearance adjustment, permitted a number of speed/clearance variations to experiment with increased solids concentrations (Allis-Chalmers provided pulleys for 600, 800, and 1000 rpm pump operation)

- a lower water-lubricated bearing and upper thrust bearing mounted on the floor plate

- the clearance measured from the inlet to the static knife to the propeller was increased from 2½ to 4½ in. to avoid build-up of peat, roots, and other debris

- the clearance between the forwarding guide and the axial wheel, and between the static knife and the axial wheel, can be adjusted so that the maximum clearance is never greater than 1.0 mm

- the grease cup arrangement was converted to water lubrication by simply connecting a water supply to the grease system. It was estimated that the system required 2-3 USGPM of clean water.

- the materials used for the main parts of the pump/macerator were as follows:
  - pump casing, sideplate, stuffing box cover, bearing housing - cast iron
  - impeller - stainless 316SS
  - column and floor plate - mild steel
  - deflector/macerator assembly - stainless CA6NM

A shop performance test of the peat pump/macerator was carried out to determine its performance on water at 1000, 800, and 600 rpm. Tests were carried out with minimum wear plate clearance at 1000 rpm to determine the maximum head and horse-power absorbed by the pump. All other tests were carried out with the maximum 1 in. wear plate clearance to determine the minimum head efficiency produced by the pump/macerator at these conditions.

The stump deflector was removed during the last test to determine how much horsepower it absorbed.

The water tests demonstrated that the pump/macerator was manufactured in accordance with Monenco's original performance specification and no difficulty was encountered in pumping water and no deficiencies or malfunctions observed worthy of note.

The overall efficiency of the unit for Test #1 at 1000 rpm with 0.03-in. wear plate clearance was 60.5%, at the best efficiency point (BEP), which is considerably higher than any of the other known peat pump/macerator designs. This higher efficiency was attributed to the high efficiency of the Allis Chalmer's basic pump design which is about 81% at BEP.

The efficiency decreased to 33.2% as expected for Test #2, when the wear plate clearance was increased to 1 in. (maximum clearance). This decrease in efficiency was due to recirculation within the impeller. It is expected that the wear plate adjustment feature will allow higher concentrations of peat slurry to be pumped and also overcome air-binding of the pump due to high air entrainment in the peat.

It was expected that the macerator and stump deflector would increase the power consumption of the unit, but that some of the work expended in driving the macerator and stump deflector would result in a higher head produced by the pump. This was not so. The head produced by the pump without the macerator but the horsepower increased by 33% approximately at the BEP. It was also interesting to note that the flow at BEP increased from 3000 to 4000 USGPM. This may be due to the suction inlet being increased from 10 to 14 in. diameter.

However, for the other test, the head was lower than expected. This may be because the head losses for the stump deflector and macerator are not proportional to the square of the speed, which is the case for the head produced by the pump, resulting in the macerator loss becoming a large percentage of the total head produced by the pump. At BEP, the head decreases by 9% when the stump deflector is removed.

Plotting the velocity vibration readings on the General Machinery Severity Chart indicated that there were no basic mechanical dynamic deficiencies and the majority of the readings were in the good and very good range, and with one reading at low flow in the fair range which could be expected at the low flow of 546 USGPM. Some readings at other flows were even in the extremely smooth range.

Field testing under actual peatland conditions will be required to determine final effectiveness of the pump and macerator design on peat slurry and to determine how design improvements can be made.

A3.5 Report: *Peat Slurry Pumping Demonstration Project*
Contractor: Carlson 7 Sweatt-Morenco Inc.

1. The peat slurry pump demonstration test was completed during summer 1985 on a New York peatland site. Besides determining the performance of the peat slurry pump and pipeline system, the field test provided a demonstration of wet peat mining technology, including an evaluation of the effectiveness of preparing peat slurries using a high pressure water jet system. The major parameters regarding the pumping and pipeline transport of peat slurry were studied.

2. Delays in project funding and start-up until late fall/early winter 1984/85 prevented the use of a virgin peatland because of anticipated further delays in obtaining environmental clearances and the period of time required for bog drainage after ditching. Therefore, peatland site selection activities were directed towards previously drained peatlands or existing peat harvesting operations, to conform to the project schedule. Final selection of an acceptable site for the demonstration project followed a review of available peat resource information for the State, discussions with various bog owners and operators, site visits to this investigation were discussed in the interim "Site Selection Report," and the Bob Murphy bog near Vestal, N.Y., was selected as the most suitable location for testing. Good access, location near a town, all of the bog controlled by one landowner, availability of all support facilities already on the property or nearby, and an existing mining permit in place to allow removal of the peat, etc., were important factors affecting final selection.

3. The following factors were considered in evaluating the suitability of the Bob Murphy bog:

   - The total area at the deposit was 3.2 acres (1.3 ha), the peat thickness varied from 13.8 to 16.1 ft (4.2 to 4.9 m), considered adequate for test purposes.

   - The deposit was characterized by lowmoor peatland (fuel peat).

   - There were no trees and few shrubs on the surface and no surface vegetation removal (e.g., trees) for the test was needed (lower preparation and site reclamation costs).

- The water supply was indicated to be adequate by the property owner (who was quite familiar with the local aquifers, e.g., Town of Vestal wells on his property).

- A suitable slurry containment area was available.

- No environmental problems were foreseen because the surrounding property was owned by Mr. Murphy who had an existing mining permit. Mr. Murphy also had machine shop and maintenance facilities, skilled mechanical tradesman and equipment, etc., available at the site from the nearby gravel and concrete operations.

- Subsequent further sampling of the site revealed higher ash values than originally indicated and it was necessary to carry out a detailed sample analysis of the site to finally select a peat layer with lowest ash content (range of 10-22% and an average of 18.2%, dry basis) situated about 6.6 to 11.8 ft (2.0 to 3.6 m) from the surface.

- The moisture content averaged 82.3% or equivalent to that of drained peatland.

- The degree of decomposition varied from 16% up to 24%, averaging 20.1% since most of the deposit was composed of fuel grade peat (an average von Post degree of humification of H6.6)

4. The following site preparation activities were carried out prior to the test:

   - 2 350 ft of access roads were constructed around the site (approx. 715 m);

   - A water supply channel was excavated (500 ft long by 45 ft wide by 7 ft in depth);

   - A 22 400 yd^3 peat slurry reservoir was constructed using on-site materials, mostly clays, silts, and gravels scraped from the floor of the reservoir for construction of the berms;

   - The surface of the peat deposit (approximately 450 ft by 250 ft) was disked prior to moving equipment on-site, to remove the growth of tall grasses and some shrubs;

   - Prior to performing the pumping trials, the entire mining area (pit, trench, sump, etc.) was laid out on the bog surface using

wooden stakes; in addition lengths of 20 ft graduated steel conduit were driven into the peat and used as depth indicators during the mining activities.

5. Various pieces of equipment had to be fabricated and/or assembled at site including:

   - A support barge was fabricated with a double-drum winch and 32-ft boom arrangement to lower and raise the peat slurry pump into and out of the mining sump.

   - A control valve station was constructed adjacent to the barge and included a stop/start electrical control for the pump, two valves to control slurry flow and an air evacuator system. The main purpose of the valves was to control the slurry flow rate during pumping operations. The air evacuator system was installed to study possible air entrainment problems in the slurry pump/pipeline system.

   - The hydromonitor system was assembled on site and includes the main low pressure water supply pump (2000 USGPM) supplying water through 100 ft of 10-in. pipeline to two high pressure booster pumps, and from there via 200 to 270 ft of 6-in. steel pipe and rubber hoses to the two hydromonitors (water jets).

   - The electrical power to operate the peat slurry pump/macerator was supplied by a GMAC 470 hp diesel-electric generator set. Energy from the generator set was fed by power cable to the 150-hp, 1800-rpm, 460-V electric motor mounted on the slurry pump.

   - A clean water supply was required for the peat slurry pump at a rate of 5 USGPM for lubrication of the main pump bearings.

   - 860 ft of 12-in. PVC pipe was assembled to convey peat slurry from the control of valve station to the spill tank located at the end of the pipeline. The individual lengths of pipe were connected either by cementing the pipes and couplings, or by a friction fit. In addition, a number of joints, particularly the elbows, were covered with small amounts of concrete to improve stability of the pipeline during operation. At the discharge end of the pipeline, a cylindrical tank was installed in the wall of the slurry reservoir to act as a "spill box" and a support for the discharge end of the pipe.

6. During the peat slurry pumping trials the following major mining and pumping aspects were studied:

   - The effectiveness of peat slurry preparation using high pressure water jets and the use of the peat slurry/macerator as a mining (and a partial processing) tool;

   - The performance characteristics of the Monenco designed peat slurry pump and pipeline system (flow rates, dynamic head, pressure loss, efficiency, power requirements, etc.) were determined under actual field conditions.

   - The effect of the stump deflector was studied, and air entrainment in the system (a problem reported in previous USSR practice requiring an air evacuator arrangement for the pipeline) was assessed. An aspect of the pump design, suggested by the pump manufacturer, involved a variable clearance between the wear plate and impeller to allow internal re-circulation of slurry which varied capacity of the pump. By increasing the clearance, increased re-circulation occurred and the air-handling ability of the pump increased. The clearance could be varied from 0.03 to 1.0 in.

   - An evaluation of the physical properties of the peat slurry was made on samples taken before and after the slurry pump, viz. viscosity, solids content, ash content, degree of decomposition and particle size distribution.

   - An evaluation was made of the degree of maceration, settlability, and dewaterability of peat slurries as prepared by the hydromonitor and peat slurry pump/macerator system.

7. During removal of the top layer of higher ash content peat, the peat slurry pump operated at a nominal 800 rpm with a 1-in. clearance between the impeller and wear plate. These initial operating parameters demonstrated the following:

   - The pump flow rate varied from 1040 to 1760 USGPM (236 to 400 m^3/h) and, as expected, was generally lower than the previous water performance tests performed at the manufacturer's plant. A total of 1 146 415 U.S. gallons (4339.2 m^3) of peat slurry, at an average of 6.4 wt.% solids concentration was pumped during the 11 test "runs."

   - The total head developed by the pump (average H = 35.5 ft) was also lower than the previous water test (H = 44.5 ft) at the best

efficiency point. However, the average slurry solids concentration was considerably higher (6.4%) than expected (4%).

- At the best efficiency point, the pump brake horsepower was higher (77 Bhp) than the water test data (70 Bhp). The 10% increase in brake horsepower can be attributed to the difference between the viscosity of the peat slurry and the viscosity of water.

- The field test performance data showed that the head produced by the pump during the pumping trials was 20% lower than the actual shop performance test results on water. This result was expected by Monenco and considered acceptable based on the previous USSR experience.

- A low pump efficiency was observed, averaging 15.7% (lower than Monenco's estimated 20% reduction in efficiency between water and peat slurry) with an average 10% higher brake horsepower requirement, and was attributed to low pumping capacities obtained when pumping surface peat containing much plants and root material. The determination of pump efficiency included the power demand to operate the complete pumping, macerating, and external propeller units and, as well, the energy losses in the power transmission system (motor to pump drive shaft) were not evaluated and therefore efficiency was not established on absolute basis.

- After a total operating time of 14 hours on varying characteristics of the surface layer peat, the pump was secured on surface and dismantled for inspection by Monenco and the manufacturer's pump specialists. Generally the mechanical condition of the pump was good, and no damage, wear, or corrosion was noted, except slight wear to the main nylon shaft. Bearings appeared to perform well.

8. During removal of the lower peat layer (lower ash content), the peat slurry pump operated at a nominal 800 rpm with a 0.5-in. clearance between the impeller and wear plate. Ten of the thirteen "runs" (changes in capacity) were with the stump deflector attached, and three "runs" were without the stump deflector ("propeller"). When comparing pump performance (with the stump deflector attached) on peat slurry to the shop tests on water, the following were noted:

   - At the medium designed pump clearance (0.5), approximately 582 100 U.S. gal. (2203 m^3) of peat slurry were pumped during 10 test "runs." The pump capacity varied from 1620 to 2220 USGPM (370 to 505 m^3/h) of peat slurry, averaging 3.7% solids concentration. This pump capacity, at the best pump efficiency point, and was assessed as acceptable.

- At the best efficiency point, the slurry pump developed a dynamic head of 58 ft with with an efficiency of 28%. These figures are 9% and 8% lower, respectively, in comparison to pro-rated pump performance data on water (H = 63.5 ft, efficiency = 30%). From this point of view the pump performed satisfactorily.

- At the best efficiency point, the average pump brake horsepower during the field test was higher (95 Bhp) than the pump performance on water (78.5 Bhp pro-rated from manufacturer's test data at 800 rpm, 1-in. clearance). The 21% increase in brake horsepower can be attributed to the difference between the viscosity of the peat slurry and the viscosity of water.

Pump performance (nominal 800 rpm, 0.5-in. clearance) with the stump deflector during the ten test "runs" as compared to without the stump deflector during the last three test "runs" gave the following results:

- At the same pump capacity, a small improvement (2%) in pump efficiency was noted.

- 3% lower brake horsepower was required when the stump deflector was removed.

- The dynamic head produced by the pump, with and without the stump deflector, was found to be the same (possibly due to a limited number of test data).

- Previous performance tests on water, with and without the stump deflector, showed a 2.1% increase in pump efficiency and a 3.8% decrease in dynamic head, without the stump deflector.

- The previous USSR data indicated a 5% change a dynamic head when the stump deflector was removed.

9. Representative peat slurry samples were prepared and analysed daily for solids content, ash content, and viscosity in the site laboratory. Solids content of the slurry varied between 1% and 7.1% (averaging 3.7%). For each test (change in pump rpm, impeller - wear plate clearance), the solids concentration during the three runs (changes in capacities) varied slightly. This was to be expected. The ash content of the slurry varied between 22.8% and 40.2%. The ash content of the slurry was somewhat higher (averaged 33.7%) than expected based on the laboratory results on the in situ peat (average 18.2% dry basis). It is possible the higher than expected ranged of ash in the peat slurry was a result of some residual contamination of the lower ash content layer (10 to 22% ash) by the upper higher ash content layer (35 to 45%

ash) removed earlier. Peat slurry viscosity results as determined by the site laboratory were almost the same as laboratory results obtained earlier on the in situ peat samples taken to characterize the site.

10. To obtain plots, data from the lower layer tests were grouped because of distribution according to solids concentration levels of 2.6%, 4.5%, and 5.9%, by weight. The pump/pipeline performance data (dynamic head versus capacity and head loss versus peat slurry velocity) for different peat slurry solids concentrations showed that the pump dynamic head decreased with an increase in slurry solids concentration. This was the result of the increase in viscosity of the peat slurry as solids content increases, resulting in increased friction losses and a reduction in the pump capacity.

11. The test results (pressure loss versus flow velocity for the lower layer peat) were quite similar to previous information available to Monenco on field tests of Swedish peat slurry, for the same diameter (12 in.) of "plastic" pipeline. They showed that higher solids concentration slurry experienced higher pressure losses than lower solids concentration slurries, for the same pump capacity.

12. A performance comparison was made between the Monenco and USSR TPD-4A peat slurry pumps. It should be noted that the performance characteristic for the Monenco pump at 1000 rpm and 0.03 in. clearance was developed from a pro-rating of test data (lower layer) obtained from the pump on peat slurry at 823 rpm, with 0.5 in. clearance, and on water test data obtained at 1000 rpm and 0.03 in. clearance. The following was observed:

    - At the best efficiency point of 48%, the TPD-4A pump capacity was 3520 USPGM or 800 m^3/h. The best efficiency point of the Monenco pump was higher (53%) either a higher flow rate (4050 USGPM or 920 m^3/h). Consequently, the brake horsepower requirement was significantly greater, at a given head, than TPD-4A pump.

    - The USSR TPD-4A pump had a larger impeller diameter but operated at lower pump rpm in comparison to the Monenco pump. The effect of a change in impeller diameter is similar to a change in pump speed; both result in a change in the speed of the slurry which leaves the impeller, and therefore the larger diameter impeller of TPD-4A pump compensated somewhat for its low speed when compared with the Monenco pump. The USSR PDT-4A pump was designed for a maximum pump speed of 600 rpm.

13. The field test data (lower layer showing the relationship between peat slurry viscosity and solids concentration has been added to previous

which were taken from the earlier Monenco report entitled data *Development of Design Parameters for Peat Slurry Pumping and Pipeline Transport*. The expected optimum peat slurry solids content for an industrial application of the peat slurry pump should be about 6% (by weight) for the type of peat as encountered near Vestal, N.Y. The differences between the average solids concentration obtained during the field tests (3.7% solids) and the optimum industrial solids concentration (6% solids) can be attributed to variations in the in-situ peat characteristics such as peat type, degree of decomposition, and ash content, as well as water addition rates.

14. Water for peat slurry preparation was provided by a low pressure pump which supplied the hydromonitors via two high pressure pumps. The maximum capacity of the low pressure pump was 2000 USGPM (7570 L/min), although the level of delivery maintained for the duration of the testing program was between 1300 and 1700 USGPM (4920 and 6440 L/min). A total of 1 702 042 U.S. gal. (6442 m^3) of water was provided by the water supply pumps during operation to prepared 1 746 427 U.S. gal. (6600 m^3) of peat slurry.

15. Performance data on the USSR model GM-2 hydromonitor were compared with data obtained during the test on the Stang equipment. For a 1.75-in. (0.044 m) nozzle using the Stang equipment, nozzle pressures recorded during testing were slightly higher than those recorded for a similar size nozzle mounted on the GM-2. Higher nozzle pressures and greater effective mining ranges of the water jets were attained during the testing as compared with the ranges reported for the USSR model. The Stang hydromonitor had an effective range of about 30 m compared to 20 m for the USSR hydromonitor.

16. During the pumping demonstration test, peat slurry solids concentrations of between 1 and 7.1% (by weight) were obtained for the lower layer peat. The water addition rate for slurry preparation was calculated based on the desired solids concentration, the moisture content of the layer being mined (80 to 86% moisture), and assumed slurry pump capacities (1500 to 2200 USGPM peat slurry flow rates).

17. Three sets of experiments were conducted to assess the degree of peat maceration occurring during the pumping test, and how it affected the settability and dewaterability of the slurry. These were as follows:

    - particle size and distribution
    - settlability
    - dewaterability

(a) Particle size distribution tests were performed on in-situ peat, sump slurry, and pumped slurry (from the discharge pipe) samples (lower layer peat) to estimate the degree of maceration occurring during the variious stages of the pumping and pipelining. Eighteen particle size distribution tests were carried out on these samples. The most obvious indication of maceration is the percentage of the various particles greater than a certain mesh size in the slurry, e.g., those greater than 2 mm before and after pumping. The quantity of particles greater than 2 mm was reduced by 55% by the pump and pipeline when the propeller (stump deflector) was used. A similar percentage reduction was experienced when the propeller was not used, though total particle weights are somewhat higher at both sampling locations. Based on only one solid peat sample, it appeared that hydromonitoring did not contribute significantly to maceration of the peat at a particle level, although it is obviously important in the breakup of large clumps of peat. However, this is expected to be peculiar to the peat found at the site and requires confirmation with further testing.

(b) Both settlability and dewaterability are peat slurry properties which are expected to have a significant effect on wet peat mining operating conditions. Both settlability and dewaterability decreased rapidly between 2% and 3% total solids. Dewaterability also decreased with increasing solids content, though this relationship appeared to follow a less dramatic curve than settlability, which was exponential. Essentially, a 2% solids slurry settled between six to nine times faster than a 5 to 6% solids slurry, although only two to three times the quantity of peat is mined in the latter. The dewaterablility rate decreased by a factor of 2 to 2.5 when the slurry solids content was doubled.

Settling is a cheap water removal process. The major costs associated with it are land area and time requirements. Dewatering is a mechanical process which needs energy input. Very preliminary analysis of settlability data suggested that the degree by which the solids content of the settled peat was increased over the slurry pumped solids content was very small. However, a complete analysis featuring a detailed comparison between the benefits of dewatering versus settlability from both a process and economic standpoint is required.

A4 DEWATERING/PROCESSING

A4.1 Report: *Investigation of Transferable Technology for Application in Peat Dewatering Research*, NRCC 24475

Contractor: A. L. Burwash Consulting Ltd.

The project described in this report was initiated in response to a concern recognized and expressed by the International Energy Agency, in which Canada is a member. Fuel-quality peat is found in abundance throughout the world's temperate zone; its use as a fuel is limited by its high moisture content of up to or greater than 90% (wet basis). Artificial dewatering technologies presently used on a commercial scale are able to economically remove peat water only to the 75% (wet basis) level; further dewatering uses more energy than it releases. Peat dewatering studies, while becoming more sophisticated, have not yet produced sufficient data to provide researchers with a clear understanding of the components or character of peats. Neither are the fundamental mechanisms of dewatering fully understood.

This study was designed to survey and document research that is being done, or that has been completed, in areas where the research methods or results hold potential for transfer to the dewatering of peat. Over 400 research personnel were contacted; government, industry, and university sections were fully represented. Extensive literature searches and reviews were carried out; discussions were held with professionals by telephone and in person. Analysis of the acquired data indicated those areas most relevant to the study; primary researchers readily became apparent.

The report reflects the methodology used by the researchers to attain the project objectives, which were:

- identification of disciplines and subdisciplines in which research work may be transferable to future studies in the fundamental aspects of peat dewatering

- identification of transferable research results and research methods from each relevant discipline or subdiscipline

- identification of researchers in universities, government agencies, and companies who have done or are currently doing relevant or transferable research

- provision of a brief explanation of the transferable research as it relates to gaps in knowledge concerning the fundamental aspects of peat dewatering

The contractors, in identifying research carried out in other fields, and gaps in current knowledge directly related to peat technology, classified the thrust of the project search requirements in the broad areas of:

- State-of-the-Art: Fundamental Aspects of Peat Dewatering
- Microbiology of Peat
- Porous Media Studies
- Physical Chemistry: Principles Actions and Characterization
- Cellulose-Lignin Degradation
- Research on Water-Binding Mechanisms
- Drying Measurements and Modelling

The search for transferable technologies led to examination of work in very diverse fields. The need to examine methods of pore characterization led to primary inquiries in civil engineering, petroleum engineering, physics, and chemical engineering. Chemical characterization needs were met in basic chemical research and in the pulp and paper, textile, and food industries. Movement of fluids in porous media is being researched in civil, chemical, petroleum, and agricultural engineering. The nature of water-holding mechanisms is being studied in fields where high moisture content materials are handled such as agricultural engineering (livestock wastes), mineral engineering (cakes and slurries), chemical engineering (sanitary wastes), and the food industry (drying and preservation of food). Microbial studies are being carried out in biology and chemical engineering departments and forestry research centres.

The search for relevant transferable technologies revealed that:

- Biological and microbially produced compounds could play a significant role in evolving more effective peat dewatering procedures. Changes in the chemical structure of peat may change water-holding capacity.

- Surface chemistry studies have direct application to fundamental research on the way in which water is held in peat.

- Well-established methods for characterization and quantification of pore space are available for use in peat studies with minimal adaptation. The conceptual framework for development and testing of models of pore configuration and fluid flow has been established. Use of these models will require adaptation and further empirical studies to provide the basis for verification.

- Characterization of the peat, followed by application of principles used by scientists for other media, will help produce the data required for a comprehensive peat dewatering research program.

- Studies on degradation of peat constituents, chiefly lignin and cellulose, may have indirect benefit in developing innovative dewatering methods.

- Interest in identifying water-holding mechanisms and assessing their relative importance is evident in several disciplines. Basic studies have revealed promising techniques for detection and analysis. Many of these studies, however, are still in preliminary stages.

- Theoretical and experimental work is being conducted on drying of hygroscopic materials. Modelling and measuring techniques are available that could appropriately be transferred to peat research.

The research subjects, methods, and results examined during the project are fully documented in the report. The study has been strongly interdisciplinary; as a result, it has brought together information from all relevant scientific and technological areas. The depth and array of information available for the use of peat researchers is clearly identified. The task of priorizing and selecting specific research subjects now belongs to the respective bodies under whose auspices this study was conducted.

A4.2 Report: ***Process Evaluation and Conceptual Design of a Plant Based on a Technical and Economic Assessment of Peat Dewatering and Peat Fuel Processes,*** **NRCC 22911**

Contractor: Montreal Engineering Co. Ltd.

TECHNICAL OPTIONS

This study has evaluated the technical options available for dewatering and drying wet-mined peat for the purpose of fuel peat production. It is assumed that the feedstock will be a macerated peat slurry with a solids concentration ranging from 6% to 10%.

A peat fuel plant may be composed of one or more of the following unit processes:

- slurry storage at plant
- thermal treatment
- mechanical dewatering
- thermal drying
- effluent treatment
- densification

The first stage of dewatering to remove the bulk of water is generally carried out by mechanical equipment, such as filter presses. This method

can reduce the original moisture content of 90 wt.% in "raw" bog peat to 70 wt.% in the filter cake, thus removing 74% of the original water.

"Thermal treatment" processes have been developed in order to enhance the mechanical dewaterability of peat slurries and to enable filter presses to reduce slurry moisture contents to 50 wt.%. Researchers in this field have found from experience that it is almost impossible to dewater "raw peat" slurries economically to less than about 70% by mechanical means. High loss of fines also contributes to the poor economics of this process. On the other hand, "thermally treated" slurries are claimed to dewater to 50% moisture content in filter presses, with lesser fines losses.

Whereas pressate from the filtration of "raw" peat slurries is considered safe for return to the bog, pressates from the filtration of "thermally treated" peat slurries are considered unsafe for discharge without treatment. The economics of thermal treatment processes are adversely affected by the cost of effluent treatment.

Further drying to reduce moisture contents below 50 wt.% is generally carried out in thermal dryers.

TECHNICAL FEASIBILITY

There are no purely technical barriers to dewatering and drying wet-mined peat slurries. All problems encountered relate to the cost-effectiveness of competing processes and to determining the real performance and cost parameters of any specific technology. A few promising processes are currently at early stages of conceptual design. They have been technically evaluated by the study to the extent of data made available, but economic evaluation has not been possible where a level of pre-feasibility cost estimation has not been achieved. New process development is often based on novel applications or combinations of conventional technologies; in such cases no technical barriers need to be surmounted, but the cost effectiveness of the concept is a major consideration. In almost every case, the pace of new development has been adversely affected by the current stability in world energy prices.

The Analysis of Evaluation of this report briefly reviews the technical aspects of the various unit processes and discusses the technologies applicable to each unit process. The report contains detailed technical evaluations of all currently known technologies.

COST RELATIONSHIPS

An economic analysis provides a detailed review of the cost relationships between comparable process units of competing technologies. All costs

presented are battery limits processing costs, which exclude costs of feedstock and effluent return to bog. Costs are broken down per unit process for more pertinent comparison of competing technologies.

Confidence in the cost resultants presented by this study is of the order of (+)30%:(-)25%, which is about what would be expected of pre-feasibility estimates.

A more important aspect of credibility than the accuracy of any particular cost figure bears to independently derived costs for comparable unit processes. The analysis indicates how this relationship is supportive.

Of the processes evaluated for dewatering and drying peat slurries from wet mined peat, that of JP-Energy and Wheelabrator-Frye appears to be the most reliable. Again, it is not so much the absolute figures of cost which are considered reliable in themselves, as the relation which the JP-Energy costs bear to other independently derived cost figures.

The Koppelman K-fuel process consists of a modular train of equipment which produces a peat fuel from relatively dry 50 wt.% moisture content peat. It is the only process of its type, and it is therefore difficult to relate its costs to the costs of other processes. However, the K-fuel cost figures may well be the most accurate of all, because they are compiled from the fabrication and construction contracts of a demonstration plant which is already under construction.

The Zimpro and ORF-Wetox wet oxidation processes are both modular, at about 25 000 dry tonnes per year, and their level of development is about the same. The cost relationship between them is supportive.

All four of the above processes thermally treat the peat in order to enhance mechanical dewatering.

Conventional filter press technology has been cost estimated for dewatering treated and untreated peat slurries. Cost estimates have also been prepared for conventional thermal drying systems.

Three entirely new developments, all of which dewater untreated wet-mined peat slurries, are reported and their costs analyzed:

- Valmet-Vapo-International (VVI)
- Sulzer
- Carver-Greenfield

These processes have been developed recently; their cost estimates may accordingly be subject to wider variation. However, it should be relatively

easy to verify the claims made in each case. If they do fulfill expectations, the VVI and Sulzer technologies would both constitute breakthroughs in dewatering peat slurries without the pollution hazard of thermal treatment. The Carver-Greenfield process is not as attractive cost-wise, but is a potential contender if the first two should falter, or if thermal treatment processes should increase in cost.

SELECTED COST COMPARISONS

From the Economic Analysis the following items are selected for summary cost comparison:

Basis A

- Plant rating: less than 50,000 dry tonnes per year of product
- Product fuel: 50% M.C. peat
- Feedstock: wet-mined raw peat slurry

Process	Cost of production C$ per D.T. of product
VVI	76.91
Sulzer	64.12

Basis B

- Plant rating: above 200,000 dry tonnes per year of product
- Product fuel: 10% M.C. or less
- Feedstock: wet-mined raw peat slurry

Process	Cost of production C$ per D.T. of product
JP-Energy	97.67
Carver-Grennfield	118.36

Basis C

- Plant rating: ORF and Zimpro at 25,000 DTPY and JP-Energy at 270 000 DTPY

- Product fuel: thermally treated slurry
- Feedstock: wet-mined raw peat slurry
- Pumping and pipelining of macerated peat slurries.
- Front and dewatering of pumpable raw peat slurries (at 6% to 10% solids) prior to or during mechanical dewatering and filter presses, with and without the use of polyelectrolytes/flocculents.
  Objective: high output with low fines loss during dewatering.
- The technology and economics of treating effluents from thermal treatment of raw peat slurries.

Process	Cost of production C$ per D.T. of product
ORF-Wetox	84.65
Zimpro	92.00
JP-Energy	49.00

It must again be emphasized that the cost relationships described are of greater significance than the costs themselves. For example, when comparing Basis A and Basis B, the former product is at 50% MC and the latter at 10%, so they are not directly comparable.

A4.3 Report: *Autohydrolysis and Fractionation of Peat via the UdeS-NRC Thermomechanical Process*

Contractor: **Université de Sherbrooke**

This work was initially undertaken to develop basic information related to dewatering of peat. Its main conclusion is that rapid autohydrolysis of peat at 175-210°C is effective in altering the hydrophilic and colloidal nature of raw peat and thus facilitating partial solubilization resulting in a solid residue with improved dewaterability.

The carbohydrate content of peat is an effective marker of the changes taking place in the material during autohydrolysis. The carbohydrates are rapidly solubilized and the treatment temperature determines the extent of solubilization. As well a significant fraction of the humic material is solubilized during autohydrolysis. The presence of additional mineral acid lowering the pH accelerates the hydrolytic processes.

A simple pressing methodology has been developed in the course of this work to determine the ease in dewaterabiltiy. A characteristic pressing time

constant has thus been defined based on the mathematical analysis of the pressing profiles. This pressing time constant decreases with the severity of the treatment.

The application of our autohydrolysis approach to Finnish peat (which was part of a collaborative project with VTT-Finland) has been made, confirming the previous results obtained with our base material, a medium to high decomposition sphagnum peat.

The rheological characteristics of peat suspensions have been experimentally studied without and with additional maceration. The suspension behaves as a pseudoplastic fluid and the power law exponent as well as the intrinsic viscosity constant have been determined for a variety of solids consistencies comprised between 7.5% and 13.5% weight. It has been established that processing at these solids concentrations is possible using appropriate pumping technology.

The autohydrolysis concepts and experiments have been initially conducted in a laboratory cascade reactor. Its extension to a 1 kg/min process development unit was made in the last part of this project. The unit, which is the basis of the UDES-NRC dewatering process technology performed well and treated concentrated macerated suspensions at 12.0-13.5% weight solids in the temperature range comprised between 175-210°C for a total high temperature treatment of 1.5 min. The results confirmed the data previously obtained in the cascade reactors. The dewaterability of the treated material was improved by the treatment at the expected levels of about 55% water content.

Two distinct directions are opened by the reported work:

(a) Peat fuel area

The dewatering approach proposed and experimentally developed in this study clearly demonstrated the feasability of rapid thermal treatment (~1.5 min at 190-210°C) for peat dewatering. The solid product obtained can be used as boiler fuel.

The recommendations in this area are:

- broaden the data base to a variety of peats
- conduct prolonged runs to test reliability of the UDES-NRC technology
- link with ongoing hydraulic mining efforts to develop an integrated project

(b) Peat fractionation area

The reported work has shown that solubilization of peat components can be readily achieved by autohydrolysis. This opens the way for a novel treatment of peat aiming at selective fractionation of the main chemical families present.

We recommend that the fractionation route be pursued as a means of developing low cost concentrates for fermentation as well as chemicals and new polymeric materials derived from the humic fraction.

A4.4 Report: *The use of Microbes in the Dewatering of Fuel Grade Peat - Part 1*, NRCC 24151
Contractor: McGill University, Department of Chemical Engineering

This research has demonstrated that several types of biological compounds, including polymers, surfactants, and enzymes, can significantly enhance the mechanical dewatering of fuel-grade peat. The most promising compounds tested were chitosan and surfactin. Chitosan is a polysaccharide which contains amino-sugars. When these amines are quaternized, the polymer becomes a polyelectrolyte with positive charges along the chain. Surfactin is a surfactant synthesized by *Bacillus subtilis* which causes extreme lowering of the surface tension of water, to 27 mN/m. It also allows spreading of an aqueous solution of waxes extracted from peat. The cost difficult peat to dewater encountered in our study was that obtained from Barrington, Nova Scotia. This is a highly decomposed peat (von Post of H9). Treating this peat with the biological dewatering agents before pressing increased the amount of water removed by up to 60%.

A preliminary study revealed that combining heating pretreatment and biological additions caused substantially better dewatering than either process alone. If the Barrington peat was heated at 125°C for 20 min before pressing, the amount of water removed was increased by about 60%. If the biological agents were added to the peat between heating and pressing the water released was increased by 100%, achieving a moisture content of 61% compared to 78-80% for the controls.

The water expressed from the various peat samples with the use of various additives and treatment procedures contained dissolved and suspended carbonaceous solids. With the addition of small amounts of other nutrients to these water samples it was possible to grow many different bacteria and yeasts. Using the BOD-causing materials expressed from the peat as the carbon source for these microorganisms, it was possible to produce

significant yields of biopolymers and biosurfactants. In particular, it was possible to produce the dewatering agents chitosan and surfactin.

This research has shown the technical feasibility of a "self-contained" process. Biological materials can significantly improve the amount of water removed from peat by pressures less than 20 atm and using ambient or low temperatures. The organic material in the expressed water can be used as a substrate to produce the biological agents for dewatering. Hence, the process is referred to as self-contained, as the additives are produced from the waste-water stream while reducing the BOD to an acceptable level.

Preliminary economic calculations demonstrated that this process is competitive with other processes which use thermal pretreatment. There is also good potential for using biological agents to improve other pretreatment processes. Thermal pretreatment methods have been proposed by J.P. Energy, I.G.T., Zimpro, Ontario Research Foundation, and the University of Sherbrooke, and they all have appreciable waste treatment requirements. The addition of biological agents to the peat in these processes would be expected to minimize the waste treatment by reducing the severity of the various methods of pretreatment. There is also excellent potential for utilizing the soluble carbon compounds in the expressed water as growth substrates to produce biopolymers, etc. Thus, our research has wide applicability. It is not limited to a single process and could be used to augment other methods of peat treatment.

A4.5 Report: *The Use of Microbes in the Dewatering of Fuel Grade Peat - Part 2*, NRCC 25034

Contractor: McGill University, Department of Chemical Engineering

Part 1 of this research had already demonstrated the feasibility of using microbial products such as polymers, surfactants, and enzymes, to enhance the mechanical dewatering of fuel-grade peat. The most effective of the biological compounds was the polysaccharide chitosan. In its charged form it can increase the amount of water removed after pressing by up to 60%. A major aspect of the second year of this research was to study the application of this polysaccharide to peat drying in more detail.

Concentration studies have shown that the optimum concentration of chitosan is 0.030 g/g of peat solids in the slurry. It is possible to further improve the extent of water loss by adding a heat pretreatment step before the addition of chitosan. The heat pretreatment used was relatively mild. The maximum temperature used was 200°C. By varying the length of the heat pretreatment and the maximum temperature, it was shown that as the amount of thermal energy increased, the quantity of extra water released after pressing also increased. However, after about 175°C the increase in the

amount of water removed started to decrease and it would not probably be worth the extra cost to use higher temperatures in a commercial process.

The effects of chitosan and heat were additive at all the preheating conditions studied. However, the magnitude of improvement as a result of the chitosan was largest at lower temperatures. In the experiments with the highest temperatures and energy input, there is still a marked improvement if chitosan is added but probably not enough to make the addition economic.

The economic significance of the chitosan addition is seen at low pretreatment temperatures. By adding chitosan, the effect of the dewatering is the same as a much higher pretreatment temperature. This dramatically reduces the amount of energy that is needed for dewatering and improves the overall energy balance for the process.

The chitosan has a second effect on the economics of the process. No matter what temperature or procedure is used, there is a potential pollution problem in the dissolved and suspended solids in the large quantities of released water. In every experiment with chitosan added, there was a significant improvement in the quality of the expressed water. The particles of suspended solid were larger than the control experiments and settled out much more quickly. This gave a clear aqueous phase and a relatively compact sludge which would be recycled into the press in a commercial process. This would have two effects: it would reduce water treatment costs and increase the amount of solids recovered from the original peat slurry.

The above results can be explained by two mechanisms - aggregation of colloidal particles by the chitosan polyelectrolyte and chemical alteration by thermal pretreatment.

The chitosan has all the properties of a polyelectrolyte. Our results show that it increases the average particle size of the peat solids after pressing. The mechanism is probably a combination of coagulation by suppression of the negative charges on the colloidal particles due to the quaternized amines on the chitosan and flocculation by bridging between particles by the charged polymers. Synthetic polyelectrolytes have the same effect. Inorganic salts, such as $FeCl_2$ and $AlCl_3$ caused some improvement but are not as efficient. This is probably because they lack the bridging potential.

The heat pretreatment would result in the loss of carboxylate and other polar functional groups on the peat solids. This would decrease the binding of water molecules due to dipole-dipole and ion-dipole interactions. Some of the water molecules could be released by either agency and at high

pretreatment temperatures much of the water the chitosan could have released would have been freed by the loss of polar groups.

The final objective of this part of the research was to further elucidate the growth characteristics of microbes on the expressed water. It had already been shown in Part 1 that many micro-organisms could be grown on the expressed water. This reduces the amount of solids in the water and produces valuable microbial products. Using one organism, *Xanthamonas campestris*, as a model system, we have been able to do continuous fermentations with peat water as the feed stock. In a commercial process the water stream would be put continuously through fermentors. The product would be recovered. The solids would be returned to the press and the water would be returned to the environment.

A4.6 Report: *Development of the Lamb Wet-Cell Burner for Energy from New Brunswick Peat*, NRCC 24430

Contractor: Lamb-Cargate Industries Ltd.

The Lamb Gasifier was developed to combust unprepared wood and bark waste at 60% moisture content (wet basis) or less, and generate clean products of combustion at low excess air levels and maximal temperatures for a wide range of processes formerly fired with fossil fuels. Fuel is dried, pyrolized, and gasified in the lower chamber and combustion of resultant gases is completed in the upper chamber. The process therefore combines combustion and gasification technology.

The physical and chemical characteristics of peat including ash and high moisture content strongly suggested the gasifier as an appropriate device for peat combustion. Interest has been expressed by Jiffy Products Ltd., Shippegan, New Brunswick, where gasifier heat output would be directed to a horticultural peat flash dryer and several ovens, replacing propane fuel.

As a first phase in the execution of such a project it was proposed that a pilot-scale equipment development and combustion test should be performed by Lamb using their 0.91 m diameter test burner. This unit was built to develop design information for the original Lamb Wood Gasifiers and required refurbishment for use with peat.

A test burner facility was constructed in which air, fuel, and flue gas streams were monitored into or out of the Gasifier in order to close mass and energy balances. Fuel was subjected to ultimate analysis and periodic checks of moisture and ash content. The flue gas was sampled and analysed using water cooled probes and particulate checks were performed.

An important aspect of equipment development was to confirm the viability of the undergrate feed system. This comprised a horizontal ram which pushed the fuel via a feed tube to a vertical screw on the vertical axis of the circular grate. The screw then conveys the fuel through the grate into the combustion chamber.

Shakedown trials indicated that the sealing effect of compressed fuel in the feed tube was adequate, though low pile and high output conditions occasionally produced back flow of smoke. Feed tube sealing is expected to improve on a full scale application.

Combustion tests indicated that the fuel pile did not have the permeability of hog fuel. In conjunction with the high specific area of the milled fuel and low particle size, rapid release of volatiles followed small increases in underfire air rate. This led to disturbances in the pile, comparable to the onset of "bubbling" fluidization. Accordingly, combustion was controlled by overfire air rate.

Tests were performed using milled fuel peat of 46, 55, and 64% moisture content (wet basis). Thermal output was 2.75, 2.43, and 1.29 GJ/h, respectively, and particulate emissions varied from 183 to 1370 mg/m^3.

The test data and similarity criteria between the test unit and commercial units strongly suggest that a full-scale test be undertaken on a field unit. Some considerations of full-scale burner control and limitations to output are presented to restrict pile gas velocity.

A5 ENVIRONMENT

A5.1 Report: *Identification of the Pollution Potential of the Harvesting and Preutilization of Peat as an Energy Commodity*, NRCC 24858

Contractor: Washburn and Gillis Associates Ltd.

The literature was reviewed to identify sources of environmental impacts resulting from the mining and pre-utilization of fuel peat in Canada and to identify possible methods to mitigate these impacts. Much of the information available from the literature applies to non-fuel uses of peat and is presented in a general manner because details are site specific.

Dry mining of peat may result in increased levels of particulates and increased acidity. Particulate levels may be reduced through the use of settling ponds and through the design of drainage ditches so runoff will filter through peat before entering receiving waters. Increased acidity of drainage water may be reduced by treating wastewater in a manner similar to acid drainage from coal mines. Impacts of hydraulic mining of peat differ from those of dry mining techniques and are dependant on the method of dewatering. Wet carbonization and partial wet oxidation are methods proposed to break down the colloidal structure of peat to facilitate mechanical dewatering. The wastewater treatment techniques recommended are a combination of anaerobic and aerobic treatments which aim to lower BOD, COD, and remove organics. Information on waste streams from wet carbonization and partial wet oxidation is based on laboratory studies and pilot tests rather than full scale production operations.

A5.2 Report: *Wastewater Characteristics of Five Peat Dewatering Processes*, NRCC 23758

Contractor: Ontario Research Foundation

The exploitation of Canada's vast peat reserves through wet mining and subsequent dewatering to produce a peat derived fuel has received increasing interest. Five dewatering technologies are being investigated as possible elements in the production of peat derived fuel. Three processes are based on thermal pretreatment of the peat, viz., wet oxidation by the Ontario Research Foundation, wet carbonization by the Institute of Gas Technology, and the "low-severity" process of the Université de Sherbrooke. The two non-thermal processes are the McGill University's dewatering using microbial products and the rotary press developed by the Centre de recherche industrielle du Québec. As peat contains up to 90% moisture, the dewatering of peat results in the discharge of copious wastewater. The principal objective of this work was to characterize these effluents.

A5.3 Report: *Pollution Potential of Peat Combustion, Liquefaction and Gasification*, ERCC 22859
Contractor: Monenco Limited

PEAT COMBUSTION

1. The sources of wastes for peat fuelled power plants are similar if not identical to those for the use of other fuels such as wood, coal, and oil.

2. At equivalent power generation capacity, the combustion of peat generates a greater volume of flue gas than the combustion of coal and oil.

3. In general, emissions of sulfur oxides for a peat fuelled power plant would be expected to be less than for coal and oil fuelled plants of equivalent power generation capacity. The emissions become similar in quantity as the sulfur content of coal approaches approximately 0.5 weight percent or less.

4. Monitoring of power plants in Finland indicates that emissions of nitrogen oxides from peat fuelled power plants are the same order of magnitude as for combustion of coal and oil.

5. Monitoring of power plants in Finland indicates no major differences between combustion of peat and coal as regards the emissions of polycyclic aromatic hydrocarbons (PAH). However, the results of smaller scale combustion tests and consideration of the relatively low peat combustion temperature suggest that further consideration of PAH may be warranted.

6. At equivalent power plant output, the combustion of peat and coal generates similar quantities of ash.

7. As for coal, the combustion of peat results in the emission of trace elements.

8. At equivalent power generation capacity, the operation of peat, coal, wood, or oil fired power plants would be expected to generate similar quantities and types of liquid wastes.

9. At equivalent power generation capacity, the rejected heat from a peat fuelled power plant would be of the same order as that for wood, coal, and oil fuelled stations.

10. Current and developing pollution control practices applied to coal and oil fired thermal power plants in Canada and elsewhere should be directly applicable to peat fuelled systems.

PEAT LIQUEFACTION AND GASIFICATION

1. A review of the literature and current developments indicates that technology for the liquefaction and gasification of peat is at an early stage of development. Consequently, very limited quantitative data are available concerning the pollution potential of these processes.

2. A review of coal conversion processes indicates that liquefaction and gasification results in gaseous, liquid, and solid wastes. The wastes can be expected to contain inorganic and hydrocarbon contaminants. In general, technology is available for removal of these contaminants at source.

3. Further studies will be required to assess the pollution potential of peat liquefaction and gasification processes following the availability of pilot plant data, and component and heat balances for proposed industrial operations.

A5.4 Report: ***Development of an Innovative Approach to Assess the Ecological Impact of Peatland Development: Ecological Background and Preliminary Model Development.*** **NRCC 24129**
Contractor: IEC Beak Consultants Ltd.

With the establishment of an interagency Peat Forum in 1982, the Canadian government expressed a formal commitment to investigate the potential of peat as an alternative energy resource. Program objectives include identification of environmental impacts which may arise from peat mining, and development of mitigative measures where necessary. This report is designed to contribute to the development of environmental guidelines. The study approach is based on the premise that, in order to evaluate the significance of potential environmental impacts, the structure and function of the peatland ecosystem must be understood. Study objectives include

- description of key physico-chemical and biological components of peatland ecosystems

- identification of the types of environmental disturbances which may arise from wet and dry peat mining processes

- evaluation of the sensitivity of peatland ecosystems to such disturbances

In Part I of the report, key components of peatland ecosystems are described. These include:

- hydrology
- vegetation
- physical properties of peat
- peat chemistry
- water chemistry
- aquatic ecology

Relevant concepts from multidisciplinary literature sources, including soil science, hydrogeology, ecology, aquatic chemistry, and lake ecosystem modelling, are employed to fill in gaps where direct knowledge of peatland ecosystems is lacking. In Part II, preliminary quantitative models are developed to simulate natural and disturbed conditions, based on master variables and interactions defined in Part I. Model output is oriented toward the description of aquatic impacts.

Key elements of the report are summarized in the following sections.

Hydrology

Hydrology is characterized through a mass balance equation which describes water inputs and losses, and from which the amount of water stored in the peatland may be calculated. Major components of the water balance equation include

- precipitation (P)
- ground or surface water inflow (I)
- evaporation (E)
- discharge (D)
- storage (S)

Peatlands are characterized by groundwater levels which are at or near the surface for much of the year. The zone of hydrological activity (acrotelm) is defined by the maximum depth of the water table. Short-term storage capacity and discharge volumes are determined by the water table level. The main water storage compartment is the inactive layer, or catotelm. This zone is permanently waterlogged and hydraulic exchange rates are low.

Northern temperate peatlands exhibit characteristic seasonal fluctuations in runoff volume which are related to precipitation distribution. In

peatlands which freeze during the winter, two-thirds of annual runoff typically occurs during spring thaw. In those which do not freeze, winter runoff patterns follow precipitation trends. During the summer months, evaporation reduces runoff and, in some systems, outflow may cease altogether.

Vegetation

Peatland vegetation is the precursor of peat. Thus, knowledge of the factors which affect species composition, growth, and decomposition is essential in the determination of peat accumulation rates and physico-chemical properties, nutrient, and trace element fluxes. Peatland classifications are often based on vegetational species composition, since plants are sensitive ecological indicators of climatic and hydrodynamic conditions. Successional scenarios are preserved in the peat stratigraphy.

In northern latitudes, peat accumulation rates are a function of the amount of plant material produced (as defined by net primary productivity and standing crop) and the rate at which it decomposes. Accumulation is favoured by the waterlogged, anoxic, nutrient poor conditions commonly encountered in bogs. Plant decomposition also results in the release of nutrients and trace elements into solution. These may, in turn, be complexed with the peat taken up by living plants or leach from the system.

Peatlands, and especially bogs, have traditionally been considered to be nutrient-poor. However, while total nutrient concentrations in peatlands may often be lower than those of mineral soils, it appears that bioavailability rather than supply may limit growth. Nitrogen and phosphorus are contained largely in organic compounds. Biologically-mediated mineralization to inorganic (bioavailable forms) is tightly controlled by oxygen supply and acidic conditions.

Plant decomposition in ombrotrophic systems may also introduce trace contaminants into the soil solution. Sphagnum and other bog species have been shown to accumulate heavy metals introduced by atmospheric deposition.

Physical Properties of Peat

Classifications of peat for commercial uses are generally based on physical characteristics, since these determine water retention capacity and hydraulic conductivity. Most commonly measured physical properties (i.e., bulk density, von Post scale, fibre content) are indicators of decompositional state and, as a result, all are statistically intercorrelated.

Peat exhibits a wide range in hydraulic conductivity (10^{-9} - 8 cm/s). This can be related to differences in botanical origin and decompositional

state, depth within the profile, and compaction. Poorly decomposed Sphagnum peats exhibit the highest conductivities. Conversely, water retention capacity is highest in well-humified peats, with small pore spaces.

Chemistry

The peat-pore water complex is highly chemically reactive. It is influenced by the amount and source of water input and, in turn, determines the quality of the discharge waters. Significant differences are observed between the peat and water chemistry of ombrotrophic and minerotrophic systems. Bogs characteristically exhibit higher concentrations of acidity-related parameters such as (acidity), colour, humic and fulvic acids, trace metals, and low pH. Fens exhibit higher concentrations of parameters which reflect telluric influence: calcium, magnesium, alkalinity, and electrical conductivity, and slightly acidic to circumneutral pH.

The acidity of ombrotrophic systems has a major influence or discharge quality. Recent studies suggest that low pH's are maintained largely through the dissociation kinetics of weak organic acids. Trace metals are solubilized under acidic conditions. Most peat profiles show sharp drops in metal concentrations below the zone of water table fluctuation. The resistance of organic-dominated systems to pH changes as a result of mineral acid input through acid rain has received little study.

Aquatic Ecology

Peatlands discharge waters may enter the drainage system through streams, rivers, lake, or estuaries. The potential impact of peatland drainage and mining activities on downstream aquatic communities is perceived to be a major environmental concern. However, at the present time, the influence of natural peatland discharge on aquatic biota is poorly understood. Many economically important fish species occur in "brown-water" systems, which receive large volumes of peatland discharge. However, there is evidence to suggest that humic substances may exert a toxic effect on certain species. In addition, the available data indicate that undisturbed peatland discharge waters commonly do not conform to Federal Water Quality Objectives for the Protection of Aquatic Life for parameters such as pH, dissolved oxygen, nutrients, and metals. This area of peatland ecology represents a major information gap which must be resolved before the impacts of peatland development can be accurately assessed.

Mining Impacts

The literature suggests that potential aquatic impacts arising from peatland development relate to alteration of the hydrological regime and

impairment of water quality, with subsequent direct or indirect effects on aquatic biota. Currently, too few field observations have been conducted to accurately assess the magnitude or duration of impacts. Nonetheless, based on field observations and ecological reasoning, the following tentative conclusions as to the types of impacts which may occur can be made.

Hydrology

- Wet mining would appear to be less disruptive to the hydrologic regime than dry mining.

- Vegetation removal and drainage significantly alter the water balance of the system by causing a net decrease in evaporation and alteration of storage capacity.

- Increased or decreased runoff may be associated with peatland drainage.

- Peatland drainage alters stormflow response; generally decreasing by time and increasing peak runoff rates.

- Hydrologic impacts of wet mining will relate primarily to the presence or absence of an outflow and the nature of the receiving environment.

Water Quality

- In the absence of a treatment facility, peatland drainage is likely to increase the concentrations of suspended and dissolved solids and other related parameters such as turbidity, dissolved oxygen.

- Alterations in pH and other acidity-related parameters will depend on the influence of mineral-enriched groundwater and the depth of ditches. If ditches are dug to the zone of influence of the mineral layer, pH may increase.

- Water quality impacts arising from wet mining will depend on the water quality of the dredge ponds the method of release and the nature of the receiving environment.

- Preliminary studies indicate that ponds dredged to the mineral layer have significantly different water quality than peatbottomed ponds.

Modelling

The preliminary model contains hydrology, biogeochemistry, and toxicity subcomponents. Analysis contained in this report include:

- a description of the odel framework, including ultimate goals, major assumptions, rationale for choice of input parameters, and model limitations

- development of a preliminary hydrology model

- analysis of water balance in an undisturbed bog and alterations produced by wet and dry mining

- conceptual models for pH, major cations, carbon, nutrients, heavy metals, oxygen, and redox potential

- simulations of peat accumulation processes and electroneutrality balances (pH) in an undisturbed bog

- simulation of water chemistry of outflow from a bog subjected to dry mining. Parameters considered include pH, nutrients, metals, and toxicity.

Based on these analyses, a number of preliminary results can be derived. The following are viewed as the master variables for the model:

- the flow pathway and the rate of water flow
- pH
- the redox potential (Eh or pE)
- the bulk density and decay rate of the peat
- adsorption properties of peat
- soluble organics
- chemical precipitates

Hydrology

- Wet mining of an ombrotrophic bog would not substantially alter the hydrological pathways of a bog, while dry mining would induce a larger proportion of rainfall to leave via runoff.

- Simulation of the monthly height of the water table using the dynamic water balance equation shows reasonable agreement with published data.

- Both hydraulic conductivity and vertical piezometric gradient should be measured to assess the significance of vertical transport in anaerobic bog waters.

Geochemistry

- The fulvic acid system and chemical electroneutrality are used to model the pH of anaerobic ombrotrophic bog waters. This system appears to be adequate to describe observations upon undisturbed bogs where the pH is 4.0. If the bog is disturbed (i.e., dry mining), the modelling analyses suggest that the oxidation of ammonia (and other reduced species) and the production rate of humic substances have a critical effect upon the calculated pH in the outflow. In the case of dry mining, the inorganic carbon buffering system and the effects of pH upon the pK of fulvic acid must be included in the model to adequately predict pH increases above pH 5.

- Oxygen consumption and denitrification are used to estimate the significant zones of redox change in the peatland. Calculations presented in the report assume that methane transport from anaerobic layers can explain oxygen consumption rates. Other sources of oxygen consumption (POC, nitrification) will be considered in the future.

- Ionic, organic, and particulate phases of metals are the main forms used in the model. For Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Fe^{2+}, and Al^{3+}, it is assumed that adsorbed forms are the main particulate phase. For other divalent metals (e.g., Ca^{2+}, Mn^{2+}, Cd^{2+}), it is assumed that a metal sulphide precipitate is the main form in anaerobic saturated zones.

- The desorption rate of adsorbed metals and the dissolution rate of precipitates, together with the hydrological pathway, are the critical parameters influencing metal concentrations in the bog effluent under dry mining conditions. The calculated concentrations range over two orders of magnitude given plausible estimates for these parameters. The calculated concentrations generally bracket water quality standards (higher and lower), indicating the need for more accurate measurements (desorption rate, dissolution rate).

Toxicity

- Calculations are presented which demonstrate how fulvic acids - metal complexation decrease metal toxicity.

RECOMMENDATIONS FOR FUTURE WORK

Future studies should concentrate in two general areas:

- filling in information gaps in our understanding to peatland ecology
- model refinement, calibration and verification

Peatland Ecology

Many dynamic properties of peatland ecosystems are poorly understood. Consequently, there are inconsistencies in the literature data which may be the result of natural variability, experimental error, or inadequate baseline data. Major components requiring further study include:

- integrated data collection

- quantitative studies of hydrological regime

- aspects of the behaviour of organic acids produced by peat decomposition including
  - buffering capacity - influence of acid rain
  - kinetics of metal sorption and release under varying reduction - oxidation conditions and pH
  - aquatic toxicity of humic and fulvic acids
  - development of acid-resistant strains of aquatic biota

Modelling

A major field study to collect a complete set of site-specific data from which model calibration can be derived is required. This should be augmented by in situ and controlled laboratory experiments where necessary.

Model refinements may include the following:

- present efforts have neglected the effects of plant growth upon biochemical transformations

- more steady-state modelling calculations will be made in the future to complete the test set of data

- coding will be completed. The effects of vegetation growth need to be included in order to calibrate the model for an existing peatland and in order to provide confidence in using it to assess the effects of mining upon existing peatlands (which are actively growing).

- a finite difference model, which considers up to eight layers of different permeability, has been coded, but not debugged for the generic peatland. The model will be refined and results incorporated into the hydrology model and into hydrological pathways of the biogeochemical model.

A5.5 Report: *Fish and Wildlife Use of Peatlands in Canada*, NRCC 21238
Contractor: IEC Beak Consultants Ltd.

This report summarizes geographical distributions, composition, diversity, and relative abundances of fish and wildlife groups associated with Canadian peatlands. Potential environmental impacts of peat mining or disturbance of aquatic and terrestrial ecosystems are examined, and impact mitigation and reclamation strategies suggested.

Peatlands are defined as areas underlain by organic soils, where peat accumulations exceed 40 cm in depth. They are the most abundant wetland type in Canada, covering approximately 16% of the national land surface. Bogs, fens, and swamps are commonly recognized as peat formations. Major peatland areas are located in the Arctic, Subarctic, Boreal, and Temperate wetland zones.

Wildlife species diversity and abundance are low in peatlands compared to other wetland types, or ecosystems or mineral soils. Nonetheless, a small number of species are highly dependent on peatland habitats, and a larger number utilize them on a seasonal or marginal basis. Some types of peatlands (i.e., tamarack and willow thicket swamp and graminoid fens) provide highly productive wildlife habitat while large areas of open bog are relatively unproductive. The extent of habitat use is dependent on climate, topography and drainage, size, vegetational structure and composition, and degree of isolation.

Peatlands are important habitats for several small mammal species, including the Masked Shrew, Snowshoe Hare, American Beaver, Gapper's Red-backed Vole, and the Northern and Southern Bog Lemming. The Beaver is our most economically important furbearer, while the remaining species are important prey items of mammalian, avian, and reptillian predators. Several important furbearing and big game species are seasonally dependent on peatland habitats (i.e., Lynx, American Marten, Moose, Caribou).

Peatlands are utilized by both aquatic and terrestrial avifauns. Northern boreal and subarctic peatlands are internationally recognized breeding areas for waterfowl and shorebirds; large numbers of migratory waterfowl, shorebirds, and passerines utilize inland and coastal peatlands as staging and resting areas during migration. Despite their relatively low secondary productivity, boreal and temperate peatlands are ecologically important to a number of species. Wood warblers are the most abundant breeding group.

The composition, diversity, and abundance of fish, herptile and invertebrate communities of peatlands are poorly studied, but the few reports available indicate that numbers of individuals and species are low in open

waters and drainage-ways. However, flow regime and water quality of many important salmonid lakes and rivers are influenced by drainage from peatland areas.

Long-term environmental impacts to aquatic and terrestrial ecosystems are potentially associated with clearing and drainage of peatlands. Impacts include increased erosion and surface runoff, lowered water table, changes in physico-chemical properties of water and soils, direct destruction of aquatic and terrestrial habitat, increased fire hazard, and hunter accessibility.

The tolerance of individual species to habitat destruction or alteration depends on spatial and seasonal habitat requirements, population density, and behaviour. Some species benefit from peatland development; others are adversely affected. Impacts on the aquatic environment are anticipated to be more severe than terrestrial impacts. Lethal and sublethal effects, resulting from reductions in pH and oxygen levels, increased organic content, mobilization of heavy metals, interruption of flow regime, and fluctuations in temperature and salinity, are most pronounced on fish and amphibian eggs and pre-adult forms.

Incorporation of environmental considerations into the planning stages is the most effective and cost efficient method of impact mitigation. On-site impacts can be ameliorated by minimizing the width of road clearances, avoiding herbicides, and maintaining natural buffer zones between roads and watercourses and around the periphery of mine sites and drainage ditches. Blind-ended drainage channels or settling ponds will minimize water resource impacts. Reclamation should emphasize maintenance of soil saturation and rapid re-establishment of heterogenous vegetation cover.

In Canada, peatland conservation has received little attention due to the general remoteness of peatlands and a widespread attitude that they are abundant and non-productive. However, few undisturbed peatlands remain in southern Canada. Peatland sites deemed to be geographically or ecologically unique, contain critical wildlife habitat, rare or sensitive species should not be developed. The Canadian National Directory for International Biological Program Sites (LaRoi et al. 1976) identifies peatlands of national, regional, and local importance.

A6 PEATLAND DEVELOPMENT

A6.1 Report: *A Study on the Biogasification of Peat*, NRCC 20600
Contractor: ADI Limited

1.1 SUMMARY

ADI Limited was authorized to conduct a study on biogasification of peat by the Department of Supply and Services, Government of Canada, in early 1982 as a result of an unsolicited proposal submitted by ADI to the Task Coordinator - Renewable Energy, National Research Council of Canada.

This report presents a review of the literature on biogasification of peat, a discussion of current U.S. research, description of the two promising processes for biogasification, economic analyses of these two processes, and an economic comparison with certain other peat utilization schemes. Conclusions derived from this study and recommendations for future course of action related to biogasification are included in this report. An appendix to this report includes an annotated bibliography on the subject.

1.2 CONCLUSIONS

The following conclusions were reached after a study and assessment of the processes presently developed for the biogasification of peat.

1. Peat is a mixture of complex substances such as lignin, cellulose, and hemicellulose, which all have relatively low and different degrees of biodegradability; the relative concentrations of these complex substances can vary from bog to bog.

2. Biogasification of peat is technically feasible, based on the experimental studies done thus far; pretreatment of the raw peat (in a variety of ways) can significantly improve the biodegradability.

3. Two processes showing promise are (i) biogasification using alkaline-oxidative pretreatment developed by Dynatech R/D and (ii) BIOTHERMGAS developed by the Institute of Gas Technology (IGT) in the United States.

4. Both processes are in the early phase of development, viz., in the laboratory phase and have not reached the demonstration phase. More developmental work is required for both processes; BIOTHERMGAS has been studied only with respect to other biomass and is thought to be applicable to wet-mined peat. More work is required in order to adapt it to peat.

5. A preliminary economic analysis of these two biogasification processes and comparison with other peat utilization schemes showed that the lowest unit energy cost (exclusive of peat feedstock) was obtained in the Wet Carbonization Process, followed by BIOTHERMGAS Process and Wetox Process, and the highest energy cost was obtained in the Dynatech Process. However, when realistic operation and maintenance costs and scale factors were taken into account, the BIOTHERMGAS Process became less economically attractive. Wet Carbonization and Wetox were still economically quite attractive (with low unit energy cost). This analysis suggests that the production of densified peat may also be economically attractive when done on a large scale. However, one must take into account that this process requires fuel-grade peat feedstock at 50% MC, which has a higher cost than the hydro-peat used in other processes.

6. From discussions with the Ontario Research Foundation, it was learned that the Wetox Process is ready for demonstration, at a 115 t/d capacity, to produce hot water and steam. The Wet Carbonization Process is apparently ready for commercial application according to the U.S. licensee.

7. The environmental impact of the BOTHERMGAS Process effluent is expected to be minimal, compared to the possible adverse impact of a solubilized effluent from the Dynatech process.

8. The Wetox and Wet Carbonization Processes also generate high-strength wastewaters which should receive treatment before discharge. Laboratory studies have shown these wastes to be amenable to anaerobic pretreatment, which serves to further improve the energy recovery of the overall process.

9. It appears that anaerobic digestion has its greatest potential in treatment of waste streams generated in the processing of peat.

1.3 RECOMMENDATIONS

1. Further research and process development should be done on peat biogasification before this process can be exploited commercially; priority should be given to research.

2. It is recommended that Wet Carbonization and the Wetox Processes be given greater priority in the peat-to-energy programme in Canada in comparison to biogasification because of the relative economics and the present state of development of these processes.

A6.2 Report: *Anaerobic Fermentation of ORF Wetox^R Peat Pressate for the Production of Methane*, NRCC 24083

Contractor: ADI Limited

1.1 CONCLUSIONS

The major conclusions resulting from this study are listed below.

1. The results of this study indicate that WETOX^R peat pressate can be effectively treated in both the high-rate DFF and low-rate BVF.

2. The results of this study, and past experience, suggest COD loadings of 8.0 and 1.7 kg/m^3•d for the DFF and BVF, respectively, for a COD removal of approximately 60%, are reasonable (and felt to be conservative) for preliminary design purposes.

3. The practical limits of COD and BOD removals are in the ranges of 60-70 and 80-90%, respectively.

4. Approximately 40% of the chemical energy in the peat pressate effluent can be recovered, as biogas, through anaerobic treatment. This biogas contains approximately 6.0 to 6.5% of the energy content of the peat-derived fuel product.

5. The biogas production rate from the reactors was typical, with the specific methane generation rate averaging 0.31 and 0.35 m^3 CH_4/kg COD destroyed for the DFF and BVF, respectively.

6. The concentration of methane in the biogas for both reactors varied from approximately 50 to 85%, primarily in response to changing reactor pH. In a full-scale system, the biogas composition would show much less variation, and the methane content should be in the 65 to 75% range. Hydrogen sulfide concentrations were relatively low in both reactors and should cause no serious handling or environmental problems in full scale.

7. The raw biogas should be an excellent fuel for thermal drying of the peat-derived fuel; there are sufficient quantities available to raise the solids content of the mechanically dewatered peat from 50 to 62%. If higher solids are necessary, the peat-derived fuel can also be utilized as a fuel source for drying.

8. There was no evidence of biological toxicity or inhibition in either anaerobic reactor. Toxicity from furfural, hydrogen sulfide, or ammonia are unlikely unless the characteristics of the pressate change drastically from those observed in this study.

9. The upset condition which occurred in the DFF is believed to be the result of low reactor pH caused by a deliberate lowering of the reactor alkalinity. It is felt that there will be no need for pH control chemicals in either type of reactor, at moderate loadings, once the reactors have fully matured.

10. The results of this study indicate that there are adequate levels of macro- and micronutrients in the WETOX^{R} pressate for anaerobic fermentation.

11. Solids mass balance data indicate that approximately 75% of the suspended solids retained in the reactors were digested anaerobically during this short study. Further solids degradation will occur with time.

12. Solids wasting will be necessary in both reactors. Solids wasting from the DFF is accomplished automatically and is inherent in its design. Solids wasting in the BVF will not be required until after several years of operation, when the effluent quality begins to suffer because of excess sludge in the reactor. Because of its long SRT, the BVF will provide a very high degree of volatile solids digestion and can be used as a digester for any waste aerobic sludge.

13. Ammonia, and possibly hydrogen sulfide, concentrations in the anaerobic effluent will be toxic to trout. Conventional aerobic treatment will eliminate hydrogen sulfide and further remove BOD; however, to ensure adequate reduction of ammonia to produce a nontoxic effluent will require a nitrification system. Such a system is more costly, complex, and difficult to operate.

14. The nitrate concentration in the aerobic effluent should not be toxic to fish; however, there is a potential for toxicity from nitrite if significant residuals remain upon discharge.

15. The high nitrate concentrations can be a cause for concern if the effluent is not sufficiently diluted before entering streams of aquifers used for drinking purposes.

16. A possibly better alternative to discharging the nitrified effluent directly to a receiving stream would be to discharge to an excavated bog area. Perhaps disposal in this manner would preclude extensive aerobic polishing. Discharging to the bog should provide additional dilution and a significant degree of denitrification.

17. An alternative to nitrification is ammonia stripping. However, it is unlikely that stripping can be done, cost effectively, to the extent necessary to preclude a nitrification step altogether.

18. The estimated capital cost for a full-scale DFF and modified BVF, complete with 10-day aerated pond, is approximately $2.2 million and $1.4 million, respectively. These costs are for systems treating effluent from a WETOX^{R} plant processing 50 t/h of peat slurry at 10% solids. Larger anaerobic reactors can be designed and built at lower unit cost. This is especially significant in the case of the BVF because of its earthen construction. The estimated annual operating and maintenance costs for the DFF and modified BVF are $135,000 and $110,000, respectively.

1.2 RECOMMENDATIONS

The following recommendations are made in light of the findings of this study.

1. A pilot demonstration-scale study should be undertaken to verify the preliminary anaerobic design criteria developed here.

2. Further research work should be conducted on alternative methods for treatment of anaerobic effluent. It should include ammonia removal and nitrification studies and, possibly, toxicity studies.

3. There appears to be definite advantages for the discharge of the nitrified effluent (or partially nitrified) into an excavated bog area. Further study is necessary to determine the full environmental impact such a discharge will have and to determine if it merits serious consideration in full scale.

A6.3 Report: *Carbon Products from Peat*, NRCC 24492
Contractor: Montreal Engineering Co. Ltd.

An estimate of the potential demand for peat carbon products is developed by analysing information collected through a literature review, telephone and mail surveys, and field visits to current carbon product users. The objectives of the study are

- a global survey of existing commercial operations to provide information on both technical details and production costs

- a survey of processes under development including a technical assessment of their feasibility

- an analysis of Canadian and global market conditions with respect to the potential of these products for both the domestic and export markets

- a rating of the identified processes with respect to their economic viability

- recommendations for a research strategy designed to improve the economic feasibility of one or more of these processes in Canada

METHODOLOGY AND FINDINGS

The products investigated, some of their relevant characteristics, and promising applications are summarized in Table 1.

The properties of peat coke make it well suited for use as a reducing agent in electric furnaces. An increased use of electric furnaces, particularly in the steel industry, is forecast. Currently coal cokes and petroleum cokes compete for use in electric furnace applications.

The steel industry's blast furnaces consume most of the coal coke. Currently, reduced demand for coal coke is a result of cutbacks in steel production and a decreased use of blast furnaces. This increases the supply of coal coke available for use in electric furnaces.

Eighty percent of the world's petroleum coke is produced in the United States. The major market for these cokes is the aluminum industry for anode production. Reduced demand for petroleum coke in the aluminum industry increases the supply available for use in electric furnaces.

The non-communist production of activated carbon is concentrated in the United States and Western Europe. Current production levels are estimated to be approximately 60-70% of capacity. Peat can be used to manufacture all grades of activated carbons and is currently used by one European manufacturer, Norit N.V., located in the Netherlands.

The carbon black industry can be described as stable or mature, possibly in decline. Currently, 95% of carbon black is consumed in the rubber industry. Investigations during this study have determined that peat tars are not suitable as feedstock for carbon black production.

Peat wax is compared in the literature to montan and carnauba waxes. Unless unique properties of peat waxes are identified which will benefit users, peat will not be able to compete with the lower priced montan waxes.

Table 1

Peat Products	Characteristics	Applications
Coke	very reactive[1] low strength[1] low sulphur[1,2]	reducing agent in electric furnaces
Activated carbons	high volatile content can increase manufacturing costs[1] all grades can be produced from peat	survey revealed no area where peat-based activated carbons offered processing advantages
Tars	mainly aliphatic components unlike aromatic coal tar components	further research needed to identify components and extend areas of use
Waxes	similar to montan and carnauba waxes	further research needed to identify components and extend areas of use
Carbon black	need aromatic feedstock	the use of aliphatic peat tar not considered technically feasible at present

[1] As compared to coal products.
[2] Depends on peat bog selection.

Peat tar constituents are not well known at this time. They appear to have a closer resemblance to petroleum tars than to coal tars. The lack of information available on the characteristics prevented a meaningful assessment of the market potential of peat tar.

Two peat coking operations, Wielandt and Outokumpu Oy, and two processes that have been proposed as suitable, Lurgi-Salem and Lurgi Spuhlgas, were examined. Material balances and operating descriptions were supplied by the Technical Research Centre of Finland (VTT). All factors from bog selection, peat extraction, drying, and coking affect the final product.

The Ontario Research Foundation (ORF) performed exploratory tests to determine the feasibility of using peat coke in combination with a low cost binder system for use as foundry coke. Laboratory results were inconclusive but it is judged that further research is warranted.

A brief economic analysis of peat coke, based on VTT estimates of production costs and Monenco estimates of sod peat mining costs, indicate that minimum capital subsidies ranging from $7 to $22 million of the total estimated capitalized cost ($21 to $40 million) are required to bring the capital and operating cost recovery price of peat in line with current prices for industrial coal coke ($140/t). This analysis also indicated that peat coke obtained from the Outokumpu Oy process has the lowest anticipated capital and operating costs ($180-$260/t). Expected revenues from the sale of process by-products, power and briquettes, could effectively reduce peat coke costs, thus the addition of power and briquette modules to the plants might provide positive benefits. However, a market survey for the power and briquette products was not conducted.

A detailed analysis of current Canadian carbon product users, based on Statistics Canada data, was carried out. A questionnaire, developed as a result of visits to three coke users, three activated carbon users, and two tar users, was sent out to a sample of industrial users in order to determine current specifications and quantities consumed of these products. A telephone survey of industrial wax users and suppliers provided data for projecting potential consumption of peat.

The Canadian market for activated carbon can be described as mature since current annual demand (5.2 kt) has remained virtually constant since 1978. The only interest in peat activated carbons was indicated by the sugar producers. This is attributed to the extensive use of activated carbon in the sugar industry and the unique operating requirements imposed by mixing "in-house" manufactured activated carbons with commercial activated carbons. However, there was no evidence that peat-based activated carbons would be more suitable than other feedstocks for this application. In addition, the unit cost of activated carbon used is less than the national average ($0.62/kg versus $1.62/kg in 1982). The market potential for peat activated carbons is therefore considered to be low in this application.

It was determined that there is no market potential for peat based waxes or tars in Canadian industry.

EXPORT POTENTIAL

There is a maximum potential market of one million short tons for peat coke in the United States. Relatively lower prices for coal coke in the United States (the source of Canadian cokes) would put peat coke at a significant disadvantage. Large growth in activated carbon demand will depend on use of carbons in the water resource industry. Current controversy between the Environmental Protection Agency and the water resource utilities will have to be resolved. Until then, excess capacity in the American activated carbon industry may continue.

Japan, as an importer of Canadian coking coals, could be considered as a potential market for peat coke. The most promising developing area is possibly Latin America, where rapid growth in the steel industry is currently taking place. Based on this information, an estimate of the potential demand for peat products in Canada was developed.

POTENTIAL DEMAND IN CANADA

Assuming that capital subsidies can be provided to reduce the price of peat coke to competitive levels, its potential demand is defined as that which could develop during a slow but steady economic recovery, in applications that are technically feasible and will at least be considered for commercial use in the next five years. The potential demand for peat coke is shown below.

Estimated Potential Peat Coke Demand

Industry	Quantity (kt/a)
Chemical	180
Ferro-alloys	105
Mining and smelting	15
Total	300

These figures must be used given the following limitations:

1. Fourteen coke users supplied data by completing the questionnaires.

2. The start of peat production can require up to 6 years of peat bog development.

3. Suitable peat bogs would have to be identified. Users are concentrated in Quebec and Ontario with a chemical manufacturer located in Newfoundland.

4. The coke that peat would be replacing is a screened by product of blast furnace coal coke. Almost all of this coke is currently imported.

CONCLUSIONS

The use of peat cokes as a reducing agent is a promising application. However, the cokes that peat cokes would replace are by-products. Supply of these by-products is insensitive to demand, with market equilibrium

maintained by price adjustment. This increases the risk of peat coke production as

- prices of petroleum and screened blast furnace coke depend on activity in unrelated or loosely related industry

- supply of these products would continue even after the price falls below the breakeven point for peat coke. Thus increased efficiencies in peat coke manufacture provide no assurance of long term survival.

Capital subsidies would be required to bring the capital and operating cost recovery price of peat coke in line with screened coal coke. As most of the cokes currently being used originate in the United States, the benefits of import substitution may justify the subsidies.

The domestic activated carbon market is too small and segmented to support a peat-based activated carbon manufacturer. As the survey revealed no areas where peat activated carbons offered operating advantages and currentsuppliers enjoy existing economies of scale resulting from servicing large domestic markets, we cannot justify establishing a domestic peat-based activated carbon manufacturer.

RECOMMENDATIONS

- Upgrading peat through coking is not considered practical at this time as peat coke is too expensive when compared to alternate cokes.

- An economic analysis is required to investigate whether capital subsidies can be justified based on the benefits of import substitution.

- If capital subsidies are justified then suitable peat bogs, possibly close to the Quebec ferro-alloy producers, should be located. Tests with coke produced from an Outokumpu Oy process should be conducted with these producers.

- Research investigating the feasibility of manufacturing foundry coke from peat coke would be justified as foundry coke commands a price premium and is imported. This research, following on the results of the Ontario Research Foundation exploratory investigation, should address:

- minimum temperature to remove at least 90-95% of the volatile content of peat char

- form briquettes using low cost binders

- conduct reactivity tests to estimate relative consumption of peat coke in the production of cast iron

Although present market sizes would not justify the significant cost of research identifying the components of peat waxes and peat tars, this research may well open up new market opportunities.

A6.4 Report: *The Use of Peat Extracts/Pressate as a Feed Stock for Chemical and Biochemical Processes*, NRCC 24130

Contractor: Frank Maine Consulting Ltd.

This investigation was originally undertaken to examine the possibility of utilizing the soluble carbon compounds present in the large volumes of effluent from peat combustion processes such as wet carbonization, to obtain useful by-products by fermentation with *Clostridium* species. Within the first month of this sixth month study it was found that such extracts from fuel peat contain too low a concentration of fermentable substances to support any substantial microbial fermentation with these organisms. Therefore, with the agreement of the scientific authority, extracts of horticultural peat were obtained by controlled high pressure steam treatment using the Stake Technology process. It was predictable that some of the peat carbohydrate present in horticultural peat as hemicellulose and cellulose would be solubilized by analogy with wood and other lignocellulosic matter which can be fractionated into hemicellulose, cellulose, and lignin components using the Stake process. The investiga tion was considered worthwhile since fractionation of peat in this way could be used as the basis of a scheme for the total utilization of peat for chemical production, in which it would be necessary to obtain products of economic value from all the components.

When the Stake process was used under conditions found to release the maximum amount of carbohydrate, a complex mixture of sugars utilizable by very few classes of micro-organism was present in the peat extracts. However, strains of clostridia are able to metabolize such complex substrates, and investigation showed that several strains which produce butanol, ethanol, and acetone by fermentation were able to grow well with the peat extract as sole carbon source. In a preliminary investigation of butanol production by *C. acetobutylicum* and *C. butylicum*, and ethanol production by *C. thermohydrosulfuricum* using the small amounts of peat extract available, substrate utilization and solvent production were low, but these values could be increased in future investigations conducted on a larger scale in which greater control of the fermentation process would be possible. Such work would be necessary in order to judge the potential value of these fermentations as part of an industrial program

utilizing all the components of peat in economically viable ways. In contrast to results obtained with extracts of wood from steam explosion treatment, fermentation was not inhibited in the peat extracts by the presence of toxic substances, which would be a major advantage when establishing an industrial fermentation process.

The peat residue after the steam explosion treatment contained a considerable amount of cellulose not available to cellulolytic bacteria. This would become available for chemical use, or for use as a substrate for many fermentation processes when hydrolysed to glucose, if the residue were treated to remove waxes, lignin, and humic acid fractions for other useful applications. It may also be possible to solubilize more cellulose from peat by the addition of acid in the Stake steam explosion process.

The use of peat for chemical production by extraction or by fermentation frequently suggested but applied on a very limited scale in the past, may become a technically and economically feasible option by the application of modern technology. Previous reports on fermentation of peat have not been based on detailed knowledge of substrate composition, informed selection of the microorganism, or consideration of other factors which affect the success of fermentation processes. The work described here addresses some of these factors in the use of peat extracts for solvent production by fermentation.